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NOVEMBER 2019

Sky at Night

THE UK'S BEST SELLING ASTRONOMY MAGAZINE

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How Apollo 12 nearly ended before it began

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Find the Milky Way's neighbour in binoculars

DISTANCE DILEMMA
Will we ever see alien worlds up close?

Welcome

Catch the transit of Mercury and enjoy our supernova tour

As Monday afternoons go, I'm more excited than usual about the postprandial period of 11 November. The reason? This is when the transit of Mercury is taking place! Train a suitably solar-filtered telescope on the Sun from a little after midday and you'll see the disc of the innermost planet move slowly across the face of our star.

One of the rarest of orbital events, this particular Monday afternoon represents the last chance to observe any form of inner planet transit – whether of Mercury or Venus – until the 2030s, and a rare opportunity to gaze upon a world that's normally lost in the Sun's glare. You'll find background to the event in Jamie Carter's fascinating feature on page 30, helpful observing advice in the Sky Guide on page 46, and a detailed imaging guide from Pete Lawrence on page 76.

November's other date of note is Fireworks Night, and to mark the occasion we're tracking down some of the best celestial explosions on view this month in our feature on page 36. These are all remnants of some of the most enormous pyrotechnics in the cosmos – ancient supernovae which marked the final chapter in the lives of massive stars. The material ejected in these colossal events still glows today, and British Astronomical Association president Callum Potter is your guide to finding them.

We look at supernovae closer to home on page 98. Here, Shaoni Bhattacharya speaks to an astronomer in Antarctica looking for evidence of the blasts from nearby stellar explosions, which the Solar System may have passed directly through on its journey across interstellar space.

Enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale Thursday 21 November.

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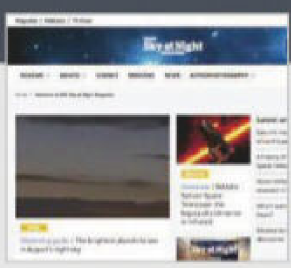
Sky at Night – lots of ways to enjoy the night sky...

Television
Find out what *The Sky at Night* team will be exploring in this month's episode on page 19



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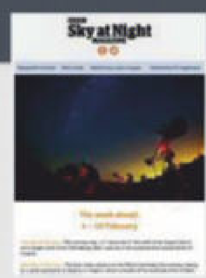

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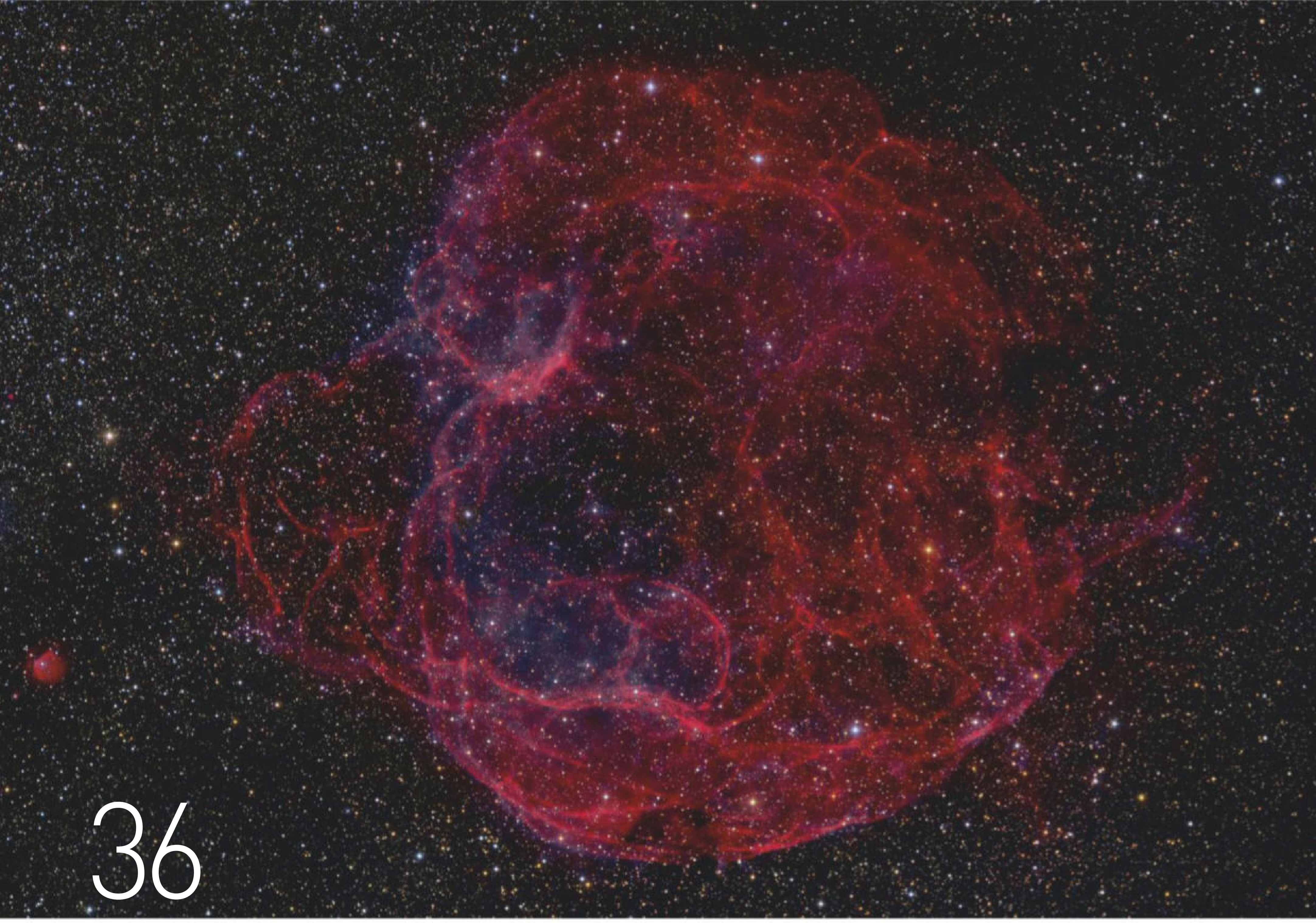

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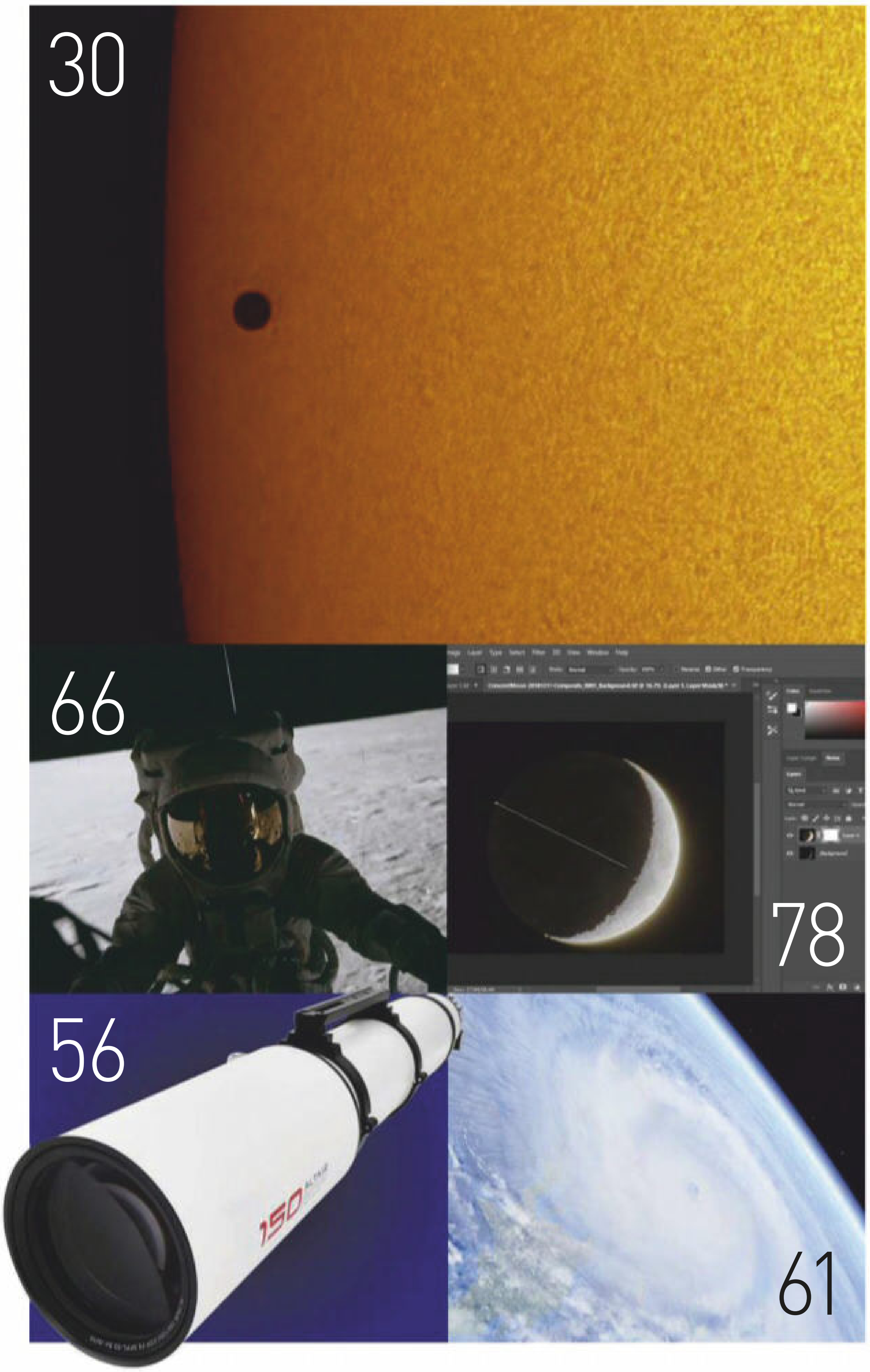
C = on the cover

New to astronomy?

To get started, check out our guides and glossary at
www.skyatnightmagazine.com/astronomy-for-beginners



This month's contributors

Callum Potter

President of the BAA

In time for Fireworks Night, Callum picks out the best celestial explosions in the night sky. See page 36

Emily Winterburn

Historian, physicist and writer

Emily explores the life of astronomer William Herschel – who discovered Uranus. See page 70

Mary McIntyre

Astronomer and astro imager

Mary shows us why making a model Moon crater can help us learn more about a lunar region. See page 73

Darryl Quantz

Public health consultant

Darryl explains how astronomers can use their skills to help save our planet. Turn to page 61

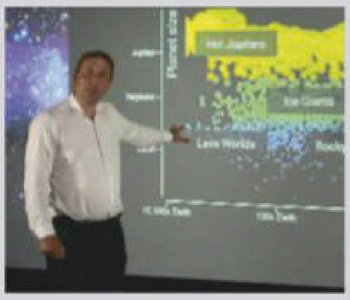
Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/Y63J542/** to access this month's selection of bonus content.

NOVEMBER HIGHLIGHTS

Exploring Earth-like exoplanets

Watch our video interview with exoplanet hunter Dr Angelos Tsiaras, part of the team that discovered water vapour in the atmosphere of Earth-like worlds



Watch *The Sky at Night*: Alien Worlds

The team examine the latest exoplanet research and meet the scientists making big discoveries around distant stars.

NEW Southern Hemisphere Guide

Download an all-sky chart, and guide to the best targets visible in southern skies over the coming weeks.

Astrophoto gallery, extra EQMOD files, binocular tour, observing forms, deep-sky tour chart, desktop wallpapers...**and much more**

PLUS: Every month

Night-sky highlights

Pete Lawrence and Paul Abel discuss the top sights to see this month.

What's going on NEXT DOOR?

Astronomers have been using one of the world's most powerful ground-based telescopes to keep a careful eye on our galactic neighbour

VISTA, EUROPEAN SOUTHERN OBSERVATORY, 13 SEPTEMBER 2019

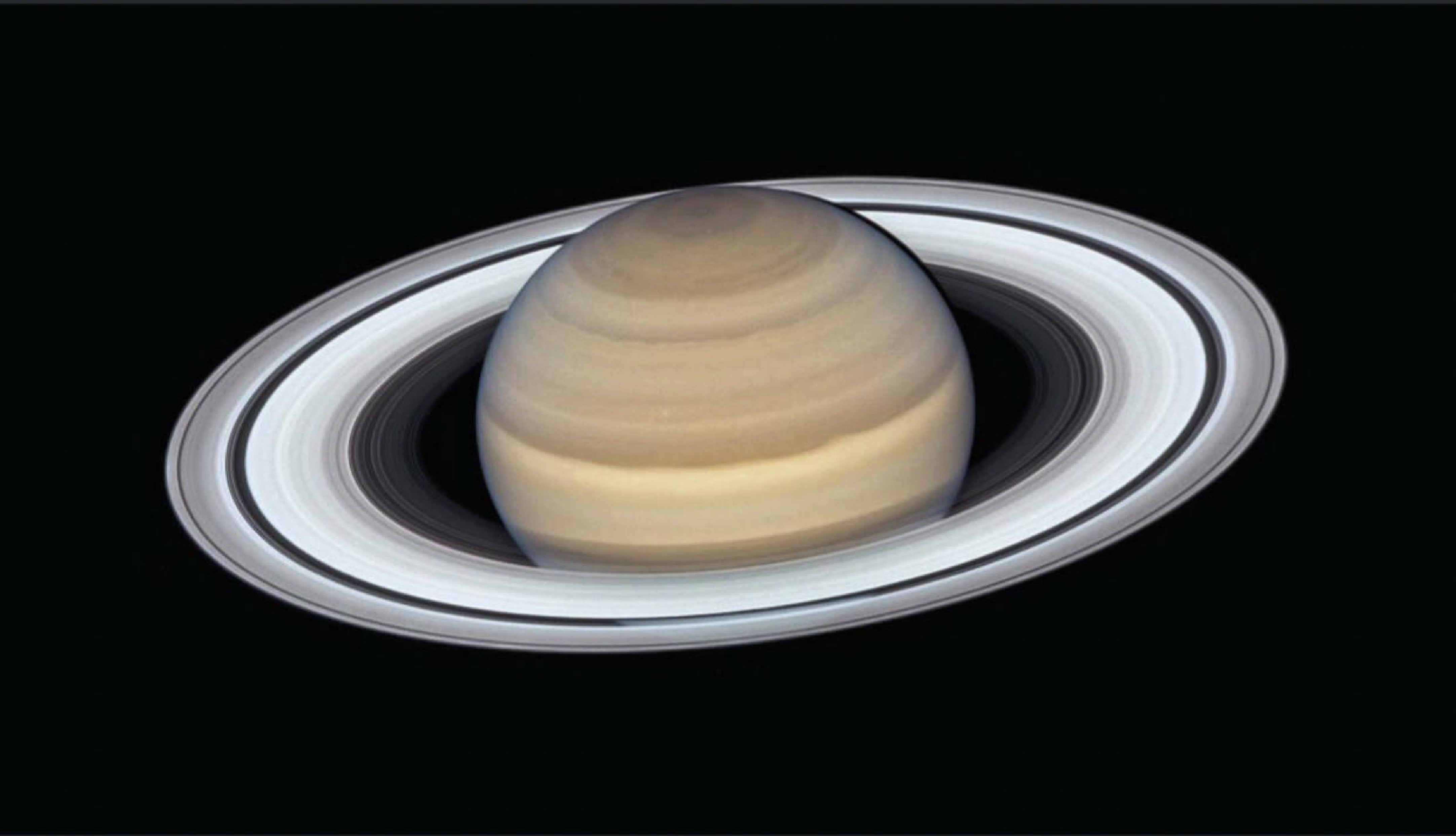
There's a lot going on in the Large Magellanic Cloud (LMC), one of our nearest galactic neighbours. And the astronomers at the European Southern Observatory have been tasked with figuring out exactly what's happening.

They're using the Visible and Infrared Survey Telescope for Astronomy, or VISTA (a modified Ritchey-Chrétien telescope with a 4.1m-wide main mirror, at the Cerro Paranal site in Chile), to keep a close eye on the LMC and, in the process, have captured this magnificent image.

The LMC floats around 200,000 lightyears from the Milky Way and the constant activity inside is due to it being home to vast clouds of dust and gas that are combining and collapsing to form new stars.

VISTA allows astronomers to observe the LMC, and its sibling the Small Magellanic Cloud, as well as their surroundings, in unprecedented detail. It's enabling scientists to study stellar evolution, galactic dynamics and variable stars within our nearby galaxies.

ESO/VMC SURVEY



△ Passing storm

WIDE FIELD CAMERA 3, HUBBLE SPACE TELESCOPE, 20 JUNE 2019

The Hubble Space Telescope took this shot of Saturn in June, as the ringed planet made its closest approach to Earth – passing within 1.36 billion km. With its rings tilted towards us the different bands that run through them are clearly seen, as is the hexagonal storm at the North Pole. A small storm below the north polar region, which Hubble spotted in 2018, is no longer visible.

Double bubble ▷

MEERKAT TELESCOPE, SOUTH AFRICAN RADIO ASTRONOMY OBSERVATORY (SARAO), 11 SEPTEMBER 2019

A vast hourglass-shaped structure has been found at the Milky Way's centre. Researchers examining the almost symmetrical pair of radio-emitting bubbles that tower above and below the central plane of our Galaxy (marked by the series of bright horizontal-running features) think they were formed by an energetic burst from near Sagittarius A*, our Galaxy's central supermassive black hole.

◁ Hot stuff

ATACAMA LARGE MILLIMETER ARRAY, HUBBLE SPACE TELESCOPE, VERY LARGE TELESCOPE, 2 SEPTEMBER 2019

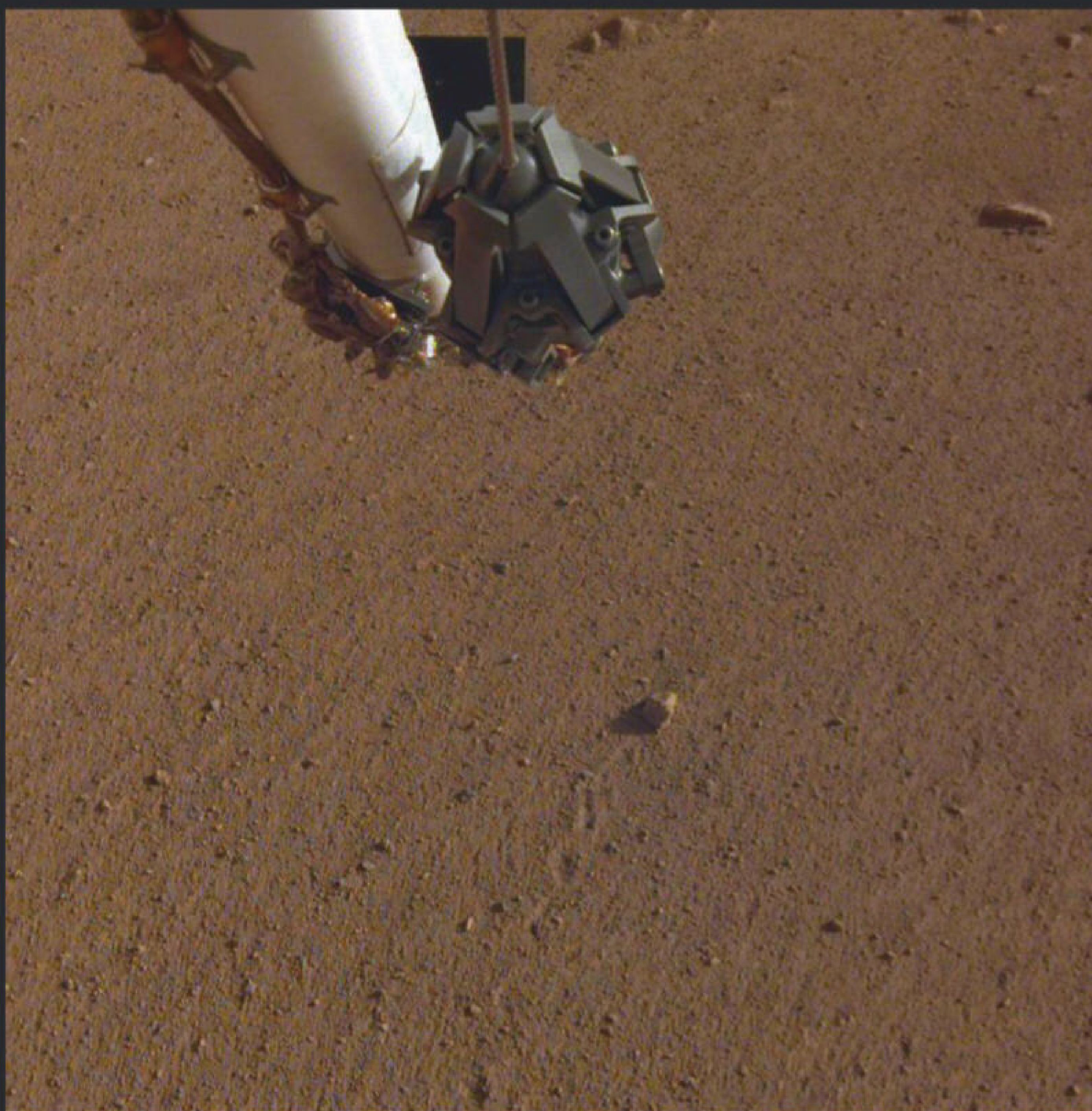
As well as hosting a busy stellar nursery, NGC 3351 is a place where stars die in dramatic style – the most recent being SN 2012aw in 2016. The latest observations of NGC 3351, which includes the image shown here, have shown stellar feedback. This is the redistribution of energy into the interstellar medium (space between stars). In NGC 3351, star formation is occurring in the ring around the galaxy nucleus at such a violent rate that bubbles of hot gas can be seen being ejected. This gas contributes to star formation.

Like a rolling stone ▷

INSTRUMENT DEPLOYMENT CAMERA, NASA INSIGHT, 26 NOVEMBER 2018

Could this be the first stroke in a game of interplanetary golf? The rock, shown here, was driven about 1m by the booster wash of NASA's InSight lander as it touched down on the surface of Mars. It may not be the longest drive in golfing history but it's the farthest NASA has seen a rock roll as a result of a craft landing on another planet.

The stone is 5.5cm in diameter, just bigger than a golf ball, and you can see the path it took in the trail left behind in the dust. Although not officially named by the International Astronomical Union, it's been nicknamed the Rolling Stones Rock.

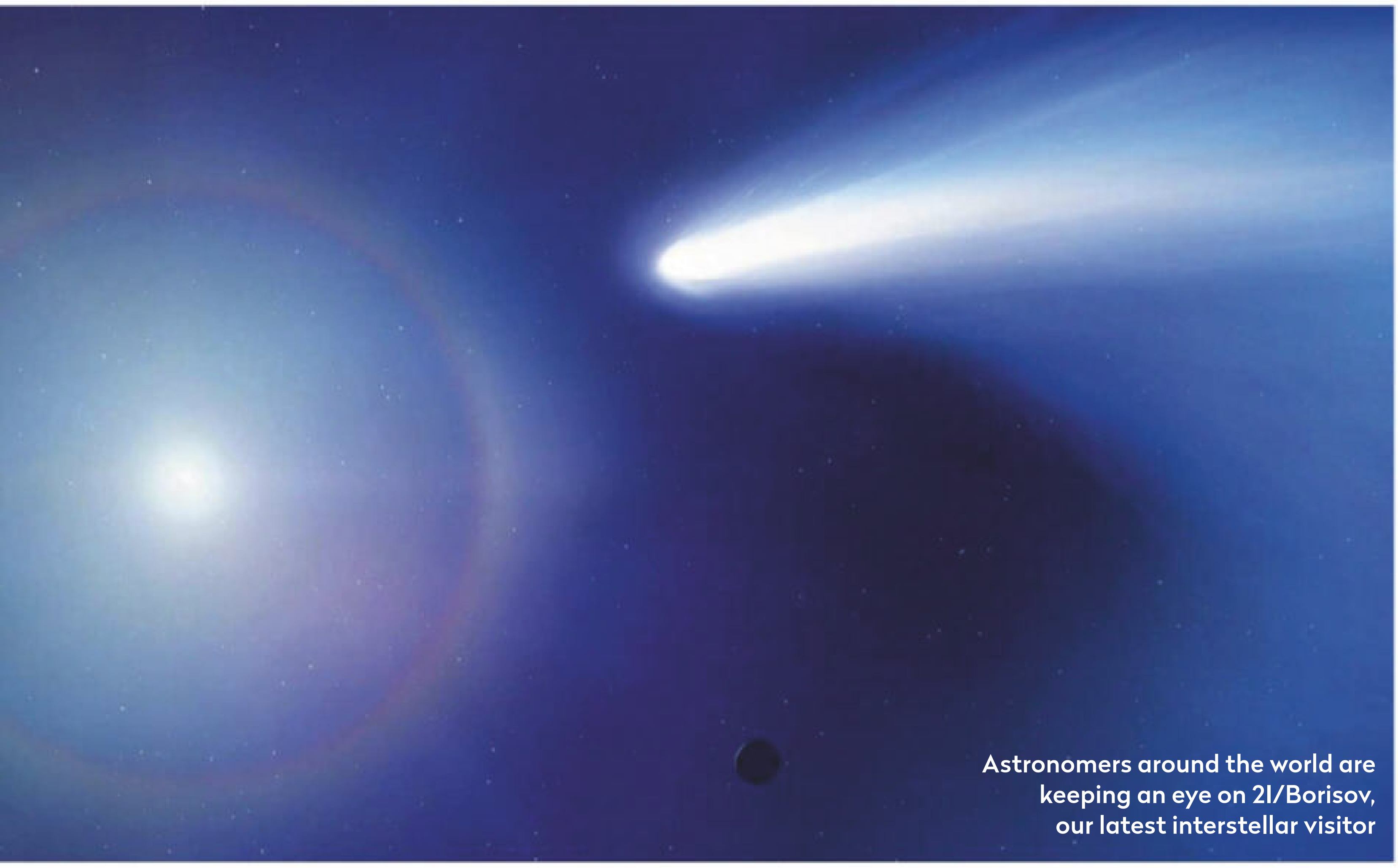


MORE ONLINE
A gallery of these and more stunning space images

NASA/ESA A SIMON (GODDARD SPACE FLIGHT CENTER) AND MH WONG (UNIVERSITY OF CALIFORNIA, BERKELEY), OXFORD/SARAO, ESO/R LEAMAN/D GADOTTI/K SANDSTROM/D CALZETTI, NASA/JPL-CALTECH

The latest astronomy and space news, written by Elizabeth Pearson

BULLETIN



Astronomers around the world are keeping an eye on 2I/Borisov, our latest interstellar visitor

Interstellar comet speeds through SOLAR SYSTEM

The cosmic visitor already appears to have a cometary tail

An interstellar interloper has been spotted entering our Solar System, the second time such a distant visitor has been discovered. The space rock, now named 2I/Borisov was discovered on 30 August 2019 by astronomer Gennady Borisov at the MARGO observatory in Nauchnij, Crimea.

As the object was observed coming in at an extreme angle to the plane of the planets – later measurements would put it at around 40° – the space rock was quickly flagged as a potential interstellar visitor. A bulletin was soon sent round, urging the world's telescopes to take a closer look.

"The comet's current velocity is high, about 150,000 km/h, which is well above the typical velocities of objects orbiting the Sun at that distance," says Davide Farnocchia of NASA's Center for Near-Earth Object Studies (CNEOS), who helped with the follow-up observations.

Even at closest approach to the Sun, 2I/Borisov won't pass within the orbit of Mars and will come no closer than 300 million km from Earth, but it should be bright enough to see through a back-garden telescope.

"The object will peak in brightness in mid-December and continue to be observable with moderate-sized scopes until April 2020," says Farnocchia. "After, it will only be observable with larger professional models through to October 2020."

In the meantime, images taken by professional telescopes such as the Gemini Observatory have revealed that 2I/Borisov appears fuzzy and is followed by a dusty tail. This suggests that the object is a comet, unlike the much more asteroid-like 'Oumuamua, the only previously known interstellar visitor discovered in October 2017.
www.gemini.edu

SCIENCE PHOTO LIBRARY/ALAMY STOCK PHOTO

Comment
by Chris Lintott

Although the unusual delights and surprises us, sometimes it's nice to witness the familiar, and so far, that's what our second interstellar visitor is providing. 'Oumuamua was weird, with its elongated shape and its refusal to behave like a proper comet.

In contrast, Borisov looks like a normal comet. Apart from its trajectory, which reveals its interstellar origins, it could be a run-of-the-mill denizen of our Solar System, and now the question is whether we should be surprised our visitors are so different?

Maybe. Though they're different in size, several theories cooked up to explain 'Oumuamua may not account for Borisov. Sometimes even normality can be surprising!

Chris Lintott co-presents *The Sky at Night*

Water world: could exoplanet K2-18b support life?

ESA/HUBBLE/M. KORNMESSER, NASA/JPL-CALTECH/SPACE SCIENCE INSTITUTE, UNIVERSITY OF MARYLAND, © ISRO

Water found on habitable world

The discovery helps to build a picture of what a planetary system can look like

Water has been found in the atmosphere of a planet in the habitable zone of another star. K2-18b is a super-Earth eight times the mass of our planet and is currently the only other known world to have both water and the temperatures needed to support life.

"Finding water on a potentially habitable world other than Earth is incredibly exciting," says Angelos Tsiaras from University College London, who led the study. "K2-18b is not 'Earth 2.0' as it is significantly heavier and has a different atmospheric composition. However, it brings us closer to answering the fundamental question: Is the Earth unique?"

Tsiaras's team took a look back at archived images of the planet and its host star – a red dwarf named K2-18 – taken by the Hubble Space Telescope. When the starlight shines through a planet's atmosphere, it picks up a signature of the elements and molecules it passes. When astronomers looked at the skies over K2-18b, they discovered the distinctive signature for water.

There may be other molecules such as nitrogen and methane, however current technology is unable to detect these. The next generation of space telescopes, such as NASA's James Webb Space Telescope and ESA's exoplanet investigator ARIEL, will be able to look into these distant atmospheres in much greater detail.

Meanwhile, new exoplanet searches, such as NASA's TESS mission, are expected to turn up hundreds of new super-Earths, particularly around red dwarfs like K2-18. Red dwarfs are the most common kind of star in our Galaxy but have low masses, meaning they are much cooler. This means their habitable zones – the region where the temperature is warm enough for water to pool on the surface – is close to the star, so any planets within the region would be bombarded with radiation. Along with the planet's large size and crushing gravity, K2-18b is considered unlikely to host life.

"This study contributes to our understanding of habitable worlds beyond our Solar System and marks a new era in exoplanet research, crucial to ultimately place the Earth, our only home, into the greater picture of the cosmos," says Tsiaras.
www.spacetelescope.org

▲ **The age of Saturn's famous rings is being questioned with research from the Cassini mission**

Are Saturn's rings ancient after all?

They could be getting a face-lift by cleaning themselves

The age of Saturn's rings has been called back into question, as a new study suggests they could be older than they appear.

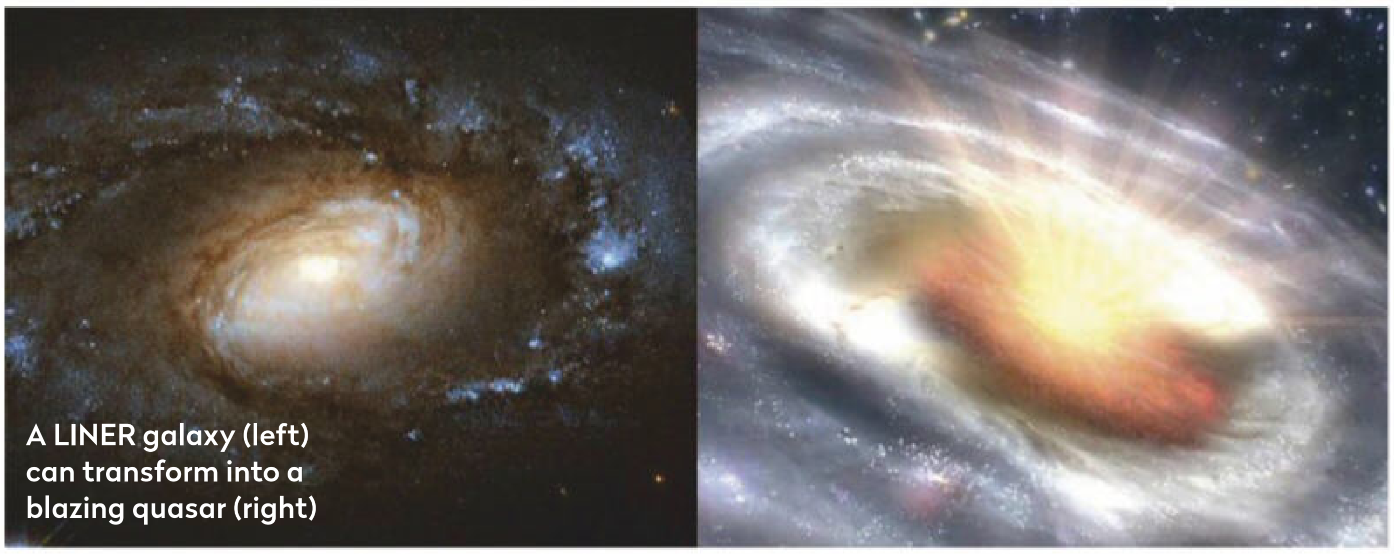
Information from NASA's Cassini space probe taken in 2017, during its dive between the planet and rings, allowed astronomers to measure how much dust had 'polluted' the ice they're made of. By working out how long this must have taken to build up, astronomers estimated that the rings are only a few million years old, much younger than the planet's 4.5 billion-year age.

The measurement, however, assumed all the pollutants stayed within the rings, but other Cassini results find the dust is falling onto the planet.

"These results suggest that the rings are 'cleaning' themselves of pollutants... thus the rings may appear artificially young," says Hsiang-Wen Hsu from the Laboratory of Space and Atmospheric Physics, who helped with the study.

http://lasp.colorado.edu/home/

Quick changing galaxies



A LINER galaxy (left) can transform into a blazing quasar (right)

A rapid transition is sweeping through six formerly sedate galaxies as their cores burst into life, according to a recent set of observations.

The galaxies are LINER (Low-ionisation nuclear emission line region) galaxies which are partially active, meaning some of their light comes from glowing hot gas around their central black holes, as well as the stars.

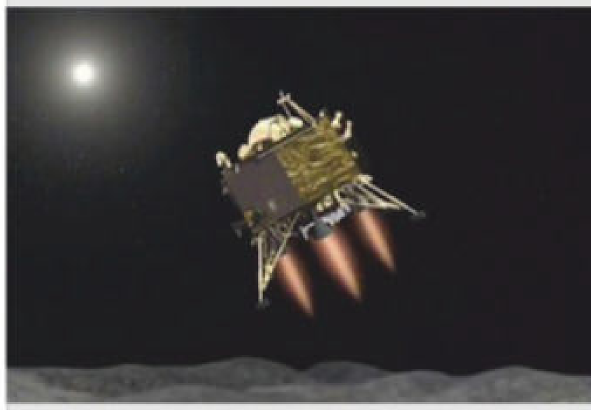
During just nine months of observations with the Zwicky Transient Facility in California, astronomers spotted six LINER galaxies that appear to be on the cusp of transforming into the most energetic of all active galaxies, quasars.

"Observing six of these transitions, all in relatively quiet LINER galaxies, suggests that we've identified a totally new class of active galactic nucleus," says Sara Frederick from the University of Maryland, who led the research.

"Theory suggests that a quasar should take thousands of years to turn on," says Suvi Gezari, also from the University of Maryland, who helped with the study, "but these observations suggest that it can happen very quickly."

www.ptf.caltech.edu/ztf

NEWS IN BRIEF



India crashes on Moon

India's lunar lander, Vikram, crashed into the surface of the Moon on 7 September. The lander appears to have flipped upside down 11 minutes into its 15-minute descent, causing the breaking thrusters to crash Vikram into the surface. The Chandrayaan-2 orbiter, which dropped off the lander, will continue its mission to study the Moon from above.

Titan's exploding craters

The latest look at Saturn's moon, Titan, suggests its craters were formed by nitrogen exploding to the surface. The moon's atmosphere is largely nitrogen, which can get trapped underground, forming gas pockets. Over time, geological heating and movement can cause the gas to expand and burst through the surface, creating a crater.

Black hole harmony

Astronomers have made out a second tone in the gravitational 'ringing' of two black holes colliding, which were originally thought too weak to make out. These additional 'overtones' will help astronomers pick apart gravitational wave signals and understand the physics that underlies their creation.

NEWS IN
BRIEF

Io volcano due to erupt
A large volcano on Jupiter's moon Io could erupt any day now. After 20 years of observations, astronomers have found the volcano, Loki, erupts about every 475 days. The cycle means the volcano should have erupted in September, but as of writing the lava vent was keeping astronomers waiting.

Turbulent galaxies
New observations by the Atacama Large Millimeter/submillimeter Array (ALMA) reveal that stellar nurseries of galaxies eight billion lightyears away (meaning we are seeing them as they were eight billion years ago) are much denser and more turbulent than those close to home. This could be why distant galaxies produce 100 times more stars than those near the Milky Way.

Red Moon rising
China and Russia have agreed to work together to explore the Moon. The nations will cooperate over the Russian orbiter Luna 26 and the Chinese polar lander Chang'e 7, both scheduled for launch in the mid-2020s. Each will supply equipment for the other's spacecraft.

NASA/JPL/USGS, MUMEMORIES/ISTOCK/GETTY IMAGES, SEBASTIAN ZENTIMOLO/UNIVERSITY OF SYDNEY X 3

BULLETIN

Rockets to explore aurora's mysteries

The project will investigate energy flows in the upper atmosphere

NASA gives green light for aurora research

The mysterious mechanisms behind the aurora could soon be revealed, as NASA has now awarded a $1.7 million grant for a set of rocket-borne experiments, run by Clemson University in South Carolina.

Its Ion-neutral Coupling during Active Aurora (INCAA) project will launch a series of rockets in 2021 and 2022, each containing a suite of instruments that will directly investigate the region of the upper atmosphere where aurorae form.

"One of the things my group will look at, in particular, is how the flow of energy from distant space enters the atmosphere and where it goes from there," says Stephen Kaeppler of Clemson University and principal investigator of INCAA. "Our research will probe deeper into how the Earth's atmosphere regulates this energy transfer and also what effects this energy input has on the atmosphere."

www.clemson.edu

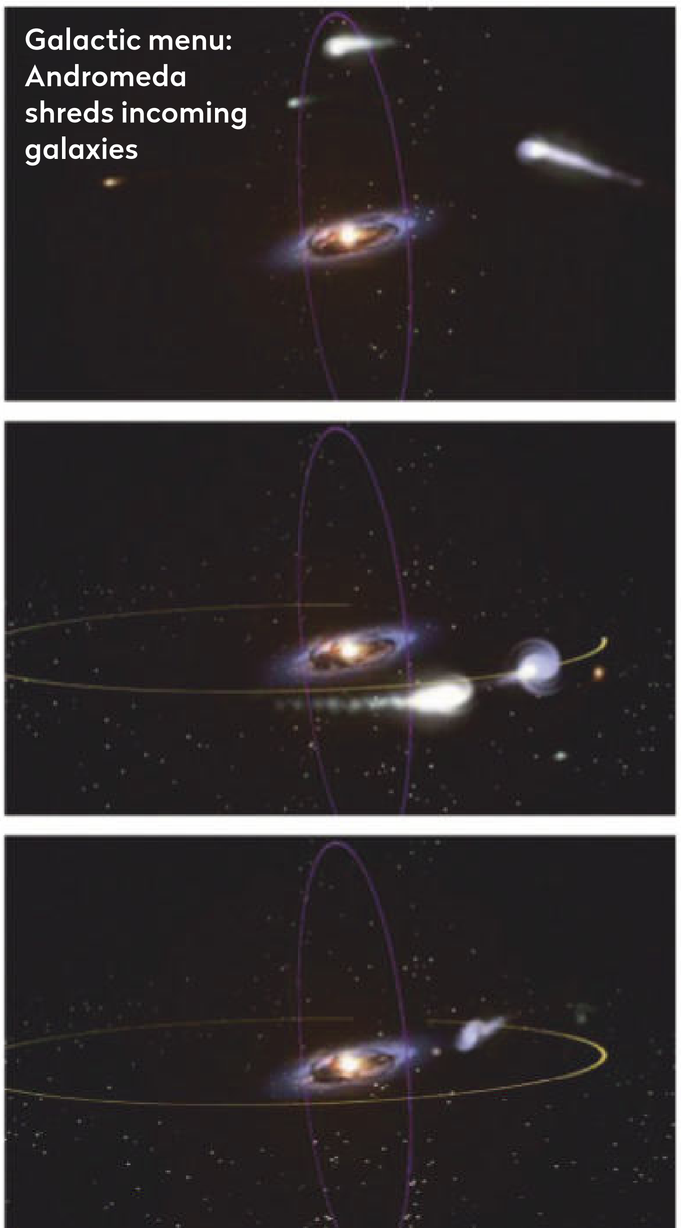
Andromeda's last meal

Astronomers have just discovered what our neighbouring galaxy Andromeda last had for lunch. Andromeda has been snacking on dwarf galaxies for billions of years, and recent observations have now tracked down the stellar leftovers of its previous meals.

"By tracing the faint remains of these smaller galaxies with embedded star clusters, we've been able to recreate the way Andromeda drew them in and ultimately enveloped them at different times," says Dougal Mackey from the Australian National University, who co-led the study.

These traces show that Andromeda was recently feeding from its plane of satellite galaxies (see yellow orbit in the images, right). This surprised astronomers, as these galaxies are at right angles to those it fed on over 10 billion years ago (see pink orbit in the images, right). However, these dwarf galaxies are only an appetiser. The main course is due to arrive in a few billion years, when Andromeda and our own Milky Way collide and devour each other to become one giant galaxy.

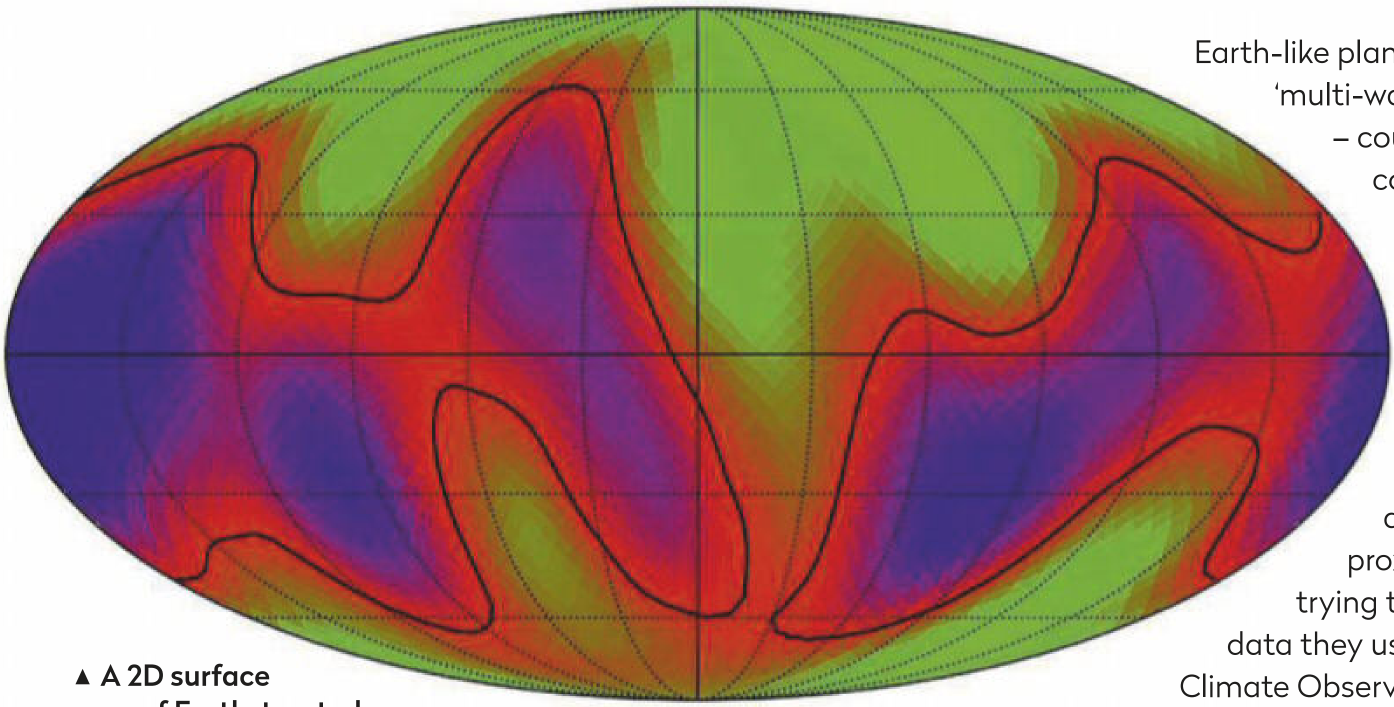
www.anu.edu.au



Galactic menu: Andromeda shreds incoming galaxies

Our experts examine the hottest new research

CUTTING EDGE



▲ A 2D surface map of Earth, treated as a proxy exoplanet, shows the continents in green and seas in blue

Can we make a map of an exoplanet?

Researchers create a rough map from a pixel-sized image of an exoplanet

Astronomers have now discovered around 4,000 extrasolar planets, a number of which are believed to be small, rocky worlds like Earth; some of these like TRAPPIST-1e may even be habitable. The usual detection methods – radial velocity and transit – can give bulk measurements such as mass, diameter and orbital distance from the star. From this information, astronomers can begin to make estimations about a world's climate and whether it would be able to host oceans of liquid water on the surface.

But what we'd really want to do is to actually see such a terrestrial exoplanet – to make out its swirling clouds and continental features in the way even modest amateur telescopes can with Mars or Saturn in our own Solar System. The problem is that until we have constructed huge telescope arrays in space – which will be very technically complex and expensive – we won't be able to spatially resolve any Earth-like planets. All we'll have is a single pixel/point and measurements of how its spectrum changes over time. So how might we derive surface maps of Earth-like planets from analysing these varying 'multi-wavelength single-point light curves' – could we watch their configuration of continents and oceans spinning under our telescopes?

SITENG FAN, SOHO (ESA & NASA)

It's the first time a two-dimensional surface map of a planet has been derived from single-point observations

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Getting started on Earth

Graduate student Siteng Fan and his colleagues at Caltech and JPL in Pasadena have been working on techniques for exactly this – by using degraded observations of Earth as a proxy for a habitable exoplanet and trying to reconstruct the global map. The data they used came from the Deep Space Climate Observatory, an Earth observation satellite positioned at the first Lagrangian point between Earth and the Sun, almost 1.5 million km away. From this vantage point the satellite's camera, which images in 10 wavelength channels (and not just the red, green and blue of your camera phone), has a continuous view of the whole sunlight hemisphere of the planet.

Fan and his team used 10,000 separate images taken over 2016–17 and averaged each one over the entire Earth's disc – recreating the type of images we could take of an exoplanet. Fan then applied statistical analyses to these simulated multiple-wavelength light curves to tease apart the signals they contained. He was able to pick out strong periodicities in the varying spectra – on both daily (the rotation of Earth's surface) and annual (seasonal changes between winter and summer solstice) scales. The results showed two clearly different sets of changes – those caused by varying cloud cover across the planet, and others caused by the continents and oceans rotating into view. From this, the team was able to recover a global view of Earth's surface.

Although it looks pretty rough, the thought of what this could represent sends shivers down my spine. This is the first time that a two-dimensional surface map of a planet has been derived from single-point observations, and it's very promising for how we'll get our first views of alien Earths.

Lewis Dartnell was reading... *Earth as an Exoplanet: A Two-dimensional Alien Map* by Siteng Fan et al.
Read it online at https://arxiv.org/abs/1908.04350

Seeing spots on distant stars

Stars appear to get fewer spots when they get older

Prof Chris Lintott is an astrophysicist and co-presenter of *The Sky at Night*

The Sun is just a star. This fact, once remarkable, is now utterly commonplace, but its implications are still being worked out. It means that the behaviour we see and study on the Sun should be replicated in many of the hundreds of billions of stars spread throughout the Milky Way, including the starspots studied by Fiona Nichols-Fleming and Eric Blackman in this month's paper.

We can easily see the Sun's spots. Even the projected image from a small telescope will show our star's activity, and the 11-year cycle that sees the number of spots rise and fall has been known for centuries. When looking at other stars, however, we need less direct methods, which is exactly what Nichols-Fleming and Blackman do here.

They used data from NASA's Kepler mission, a small telescope originally launched into space to look for exoplanets. Over the course of its career Kepler was responsible for finding thousands of exoplanets, each revealing itself by the small dip in brightness that occurs when they get in front of their parent star. Kepler's highly precise monitoring of stellar brightness turns out to be exactly what is needed to understand stellar activity.

Kepler's highly precise monitoring of stellar brightness turns out to be exactly what is needed to understand stellar activity

A dip in brightness

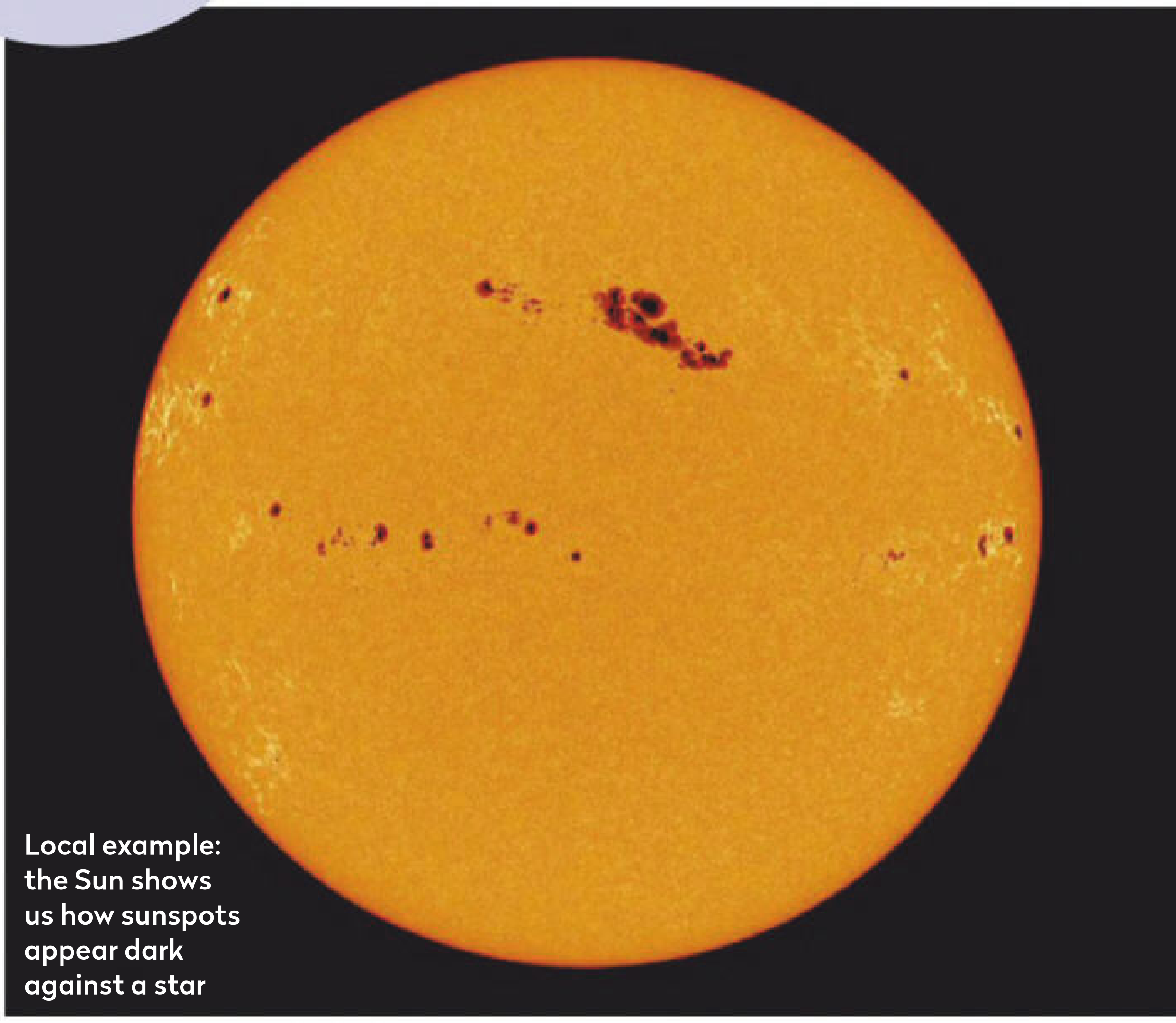
Sunspots are cooler than their surroundings, and so they appear dark against the bright surface of the star. Their presence will thus result in a dip in brightness which Kepler can detect, but the effect of an individual spot can be hard to discern among the noise and natural variability – at the level of precision of modern instruments, essentially all stars are variable stars.

Instead, the researchers assume that the amount the stars vary, averaged over time, is a suitable proxy for how much of the star's surface is typically covered by spots. That makes sense – a star prone to being spottier will have larger changes in brightness than one that only suffers the occasional pimple. That decision made, they can compare a star's spottiness to its other properties.

One area that is especially interesting is the age of the star. The new science of gyrochronology allows us to calculate the age of a Sun-like star based on its rotation period; as material is flung away from the star by magnetic activity the star slows down, leading to a gradual reduction in rotation rate over time that can be used as a clock. Using this data, the researchers were able to show clearly that, like humans, stars become less spotty with age.

Exactly how fast this decline in activity proceeds depends on the type of the star, and perhaps on the age itself. Starspots are magnetic phenomena, and magnetic fields are tricky beasts to understand.

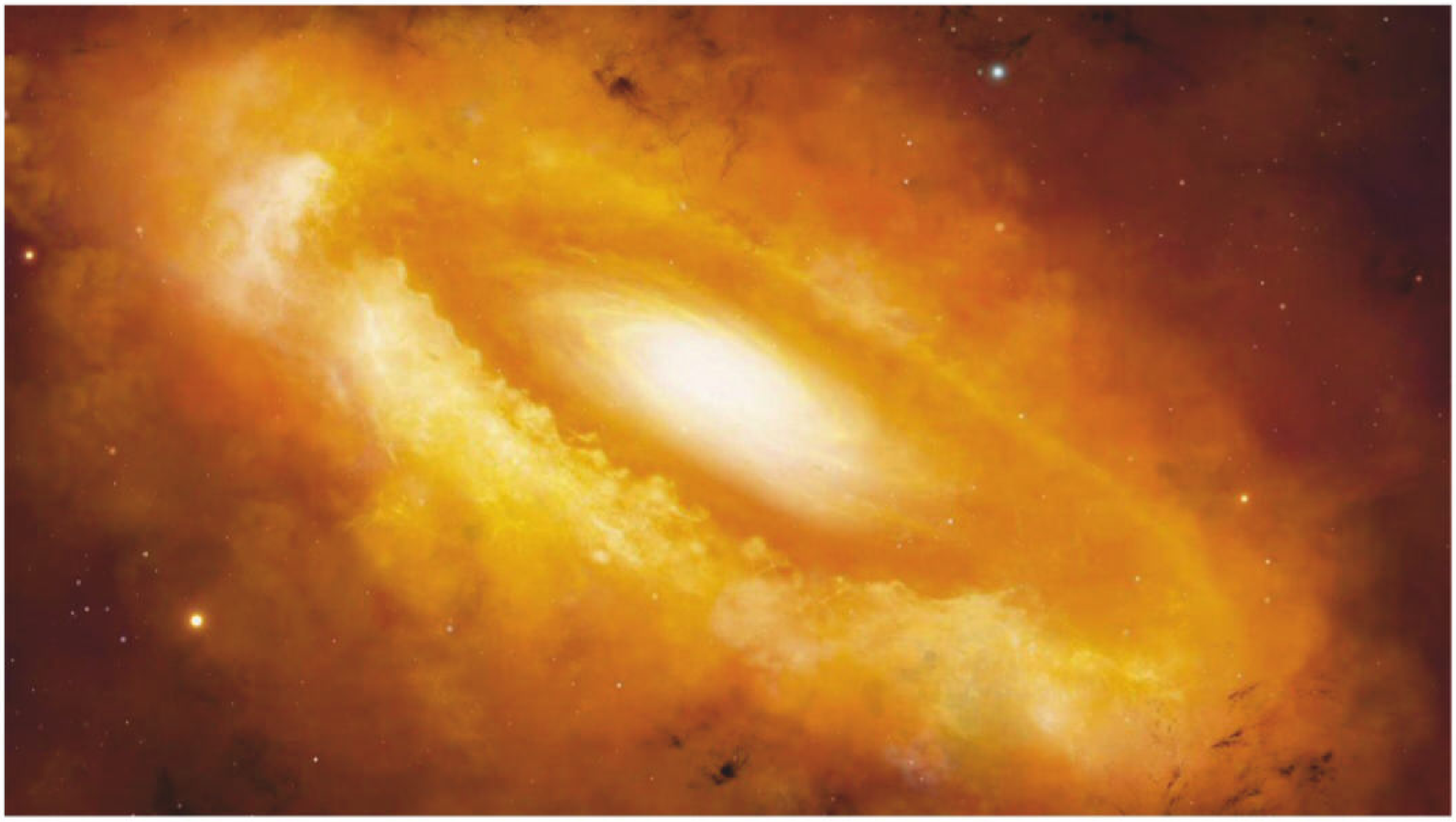
There are signs that once a star slows down to rotating less than once every 15 days, the pace of decline slows still further. That's a clue that something different is happening on these stars, but just what it is will have to wait for more sensitive instruments and much longer periods of observation.



Local example: the Sun shows us how sunspots appear dark against a star

Chris Lintott was reading... *Determination of starspot covering fraction as a function of stellar age from observational data* by Fiona Nichols-Fleming and Eric G Blackman. **Read it online at https://arxiv.org/abs/1909.03183**

INSIDE THE SKY AT NIGHT



▲ **Birth of a world: young planets form in the gas and dust in a protoplanetary disc**

MARK GARLICK/SCIENCE PHOTO LIBRARY/ISTOCK/GETTY IMAGES, BBC, ESA/ROSETTA/NAVCAM

In October's *The Sky at Night*, the team were at the British Science Festival held at the University of Warwick. The team were joined by **Prof Farzana Meru** to answer audience questions about her research

My research is on the formation of planets, and I use a variety of techniques to investigate how they grow. I get asked a lot about my methods, so here are a few of the most commonly asked questions.

Where do planets form?
Planets form in discs made of gas and dust – called protoplanetary discs – that swirl around their central star. 4.6 billion years ago our own Sun would have had one of these discs, which went on to form the planets.

How does the formation process work?
There are two ways we think planets form. The main way is via core accretion – where the dust in a disc collides, sticks together and grows to form a planetary core. As this core becomes more massive, its gravity pulls more dust and gas onto it, forming a terrestrial planet. If the core can gain sufficient mass it starts rapidly gathering gas, forming a gas giant planet. Another way in which planets can form is through gravitational instability. In the early stages of a protoplanetary disc's life, it is so massive that its own gravity causes spirals to form – similar to the spiral features in a galaxy. If the gravity in the spirals is strong enough, they can become unstable and break apart into gas balls. Eventually dust collects in the middle of these gas balls and they grow to form giant planets.

What do observed images of protoplanetary discs tell us?
We are living in a revolutionary era where powerful state-of-the-art telescopes are able to take high resolution images of protoplanetary discs, showing features such as rings, gaps and spirals. These features give us clues about how protoplanetary discs evolve and how planets form.

Some of these features may be created by planets already within the disc. We can use complex computer models and theoretical knowledge to determine if planets can exist in these discs, and even

Farzana Meru is an assistant professor and Royal Society Dorothy Hodgkin Fellow at the University of Warwick

try to constrain the properties of those planets such as their mass and orbital distance. Observations give us snapshots of what discs look like, but combined with powerful computer simulations, we have an incredible insight into how planets form and evolve.

Can we directly observe planets forming?

We are just beginning to do this. Recently astronomers have indirectly detected a planet in the disc around the star CI Tauri using a technique which measures the planet's gravitational pull on its host star. But the first direct image of a planet in a disc came last year when astronomers took an image of a forming planet around the star PDS 70. With new technological developments we hope we can detect more newborn planets.

Is our Solar System unique?

We have discovered over 4,000 extra-solar planets outside our own Solar System, and there's a huge amount of diversity among them. Based on the discoveries from the Kepler space mission, the most common type of planet out there is one that we do not have in our Solar System: a Super-Earth – approximately 10 times Earth's mass. In fact, current findings seem to suggest that our Solar System is not a typical planetary system.

Looking back: The Sky at Night

November 1970

Neil Armstrong told Patrick Moore about the Moon's "desert-like surface"

On the 18 November 1970 episode of *The Sky at Night*, Sir Patrick Moore interviewed the first moonwalker, the Apollo 11 astronaut Neil Armstrong. Ever the astronomer, one of Patrick's first questions was what could be seen in the lunar skies.

"The sky is a deep black when viewed from the Moon," said Armstrong. "The Earth is the only other visible object other than the Sun that can be seen."

The pair talked about the range of colours visible on the surface, where tans and browns were mixed in with the expected shades of grey.

"You generally have the impression of being on a desert-like surface with light-coloured hues, yet when you look at the material close up in your hand, it's charcoal grey," said Armstrong.

Armstrong signed off the interview stating his belief that humanity would build a base on the Moon "similar to the Antarctic scientific outposts" within his lifetime. Unfortunately, he did not live to see this become a reality as he passed away on 25 August 2012.

You can watch the interview yourself at **www.bbc.co.uk/programmes/p007x88t**

Rosetta: Revealing the Comet's Tale

The ESA Rosetta mission to study comet 67P/Churyumov-Gerasimenko up close is one of the most ambitious missions in history. As Rosetta officially ends, *The Sky at Night* team reveals the new discoveries that are revolutionising our understanding of comets, including the discovery that shows the crucial role these space rocks may have played in starting life on Earth.

BBC Four, **10 November**, 10pm (first repeat BBC Four, **14 November**, 7.30pm)
Check www.bbc.co.uk/skyatnight for subsequent repeat times

▲ Rosetta followed Comet 67P/Churyumov-Gerasimenko on its journey around the Sun

Emails – Letters – Tweets – Facebook – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

This month's top prize: four Philip's books

PHILIP'S The 'Message of the Month' writer will receive four top titles courtesy of astronomy publisher Philip's: Robin Scagell's *Complete Guide to Stargazing*, Sir Patrick Moore's *The Night Sky*, Mark Thompson's *Stargazing with Mark Thompson* and Heather Couper and Nigel Henbest's *2020 Stargazing*.

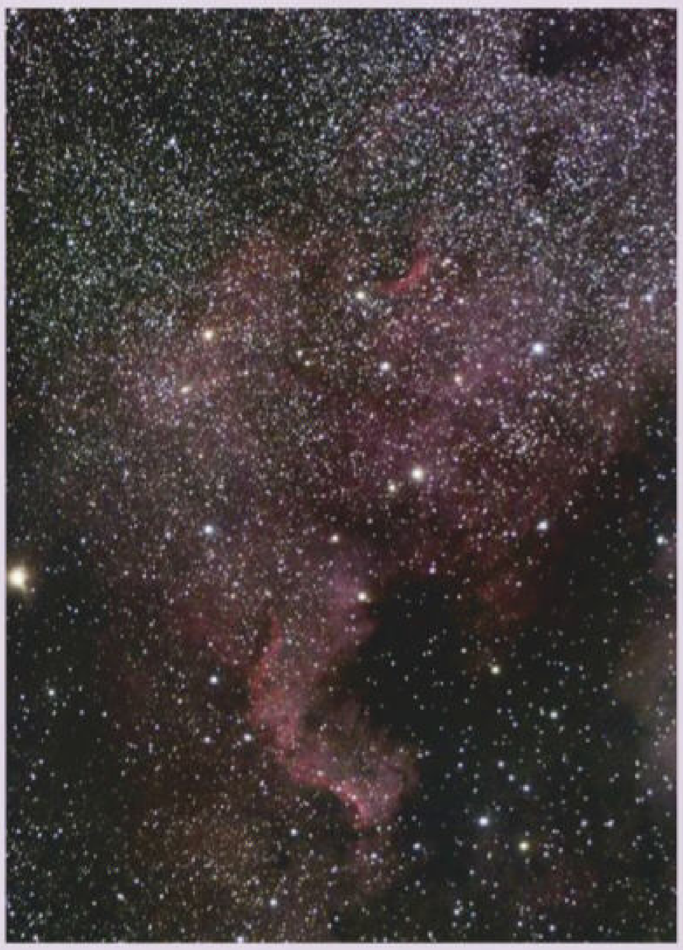
Winner's details will be passed on to Octopus Publishing to fulfil the prize

MESSAGE OF THE MONTH

Persistence pays off!

Eight weeks ago I was diagnosed with kidney cancer and underwent major surgery. Everything in life has a silver lining, and I am using my enforced sick leave to overcome a particular demon that has haunted me over the many years I have been an amateur astronomer, which is my total inability to take a good photograph of a night-sky object. I am sure that many readers will sympathise with this plight. I bought a second hand QHY10 single-shot colour camera, a 'proper' astro camera, pulled out the HEQ5 Pro mount and Sky-Watcher Equinox 80ED telescope, annoyed my wife by setting it up in the garden in a semi-permanent fashion, took over the dining room table, got advice from those amazing people at our local astronomy club (Rosliston Astronomy Group) and set to work. Of course, the next six weeks were almost completely clouded out, I found it difficult to obtain focus, work out the exposure settings, polar align the mount, even understand what those experts at the club were talking about. But persistence paid off and, while it may not be the world's best image, I am very proud of my photo of the North America Nebula. For any readers out there feeling like this photo thing is too much, my advice is keep persisting because when it works the results are amazing.

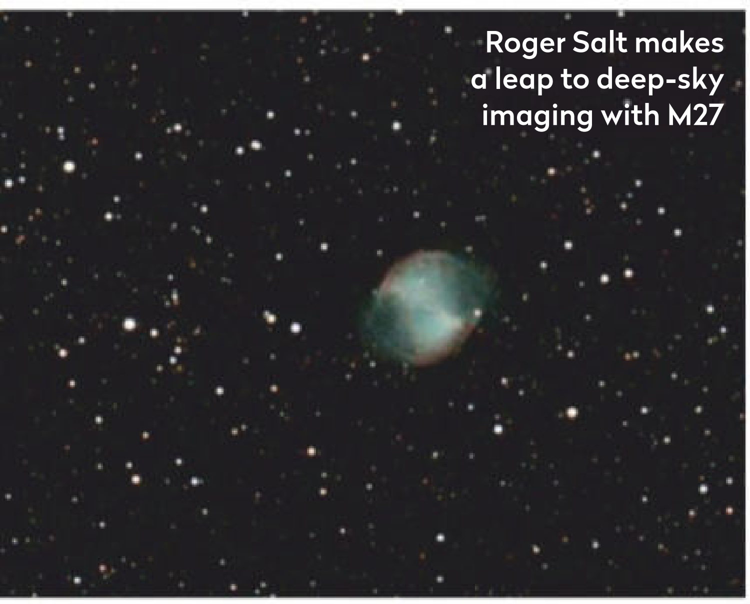
Andrew Thornett, Lichfield



► Rising to the challenge: "I am very proud of my photo of the North America Nebula"

Your fortitude is inspiring, Andrew. Hoping you image your way to a speedy and full recovery. ***– Ed***

A new perspective



Roger Salt makes a leap to deep-sky imaging with M27

The community of amateur astronomers will not need reminding of the frustrations of this great hobby but we will always return to the telescope because of one awe-inspiring view. As a young boy, two simple lenses, some postal tubes and a cotton reel enabled me to build a rather crude refractor with which to observe Jupiter and the Medici moons just as my hero, Galileo, had done. Following this revelatory experience, a series of second-hand refractor, reflector and Cassegrain telescopes have provided a lifetime of astronomical interest. While these instruments gave me satisfactory views of the Moon and planets, the majority of deep-sky objects remained invisible or at best faint smudges of light. This long-standing frustration has been alleviated through my ownership of a new Stellina telescope, which seems to cope well with light pollution and atmospheric turbulence. These are early days yet but I am impressed and would like to share with you my first effort in obtaining an image of M27, the Dumbbell Nebula.

Roger Salt, Sutton Coldfield


Night of the Hunter: Roger Samworth captures Orion

Hunting high

This picture (above) tells a story, which goes like this: I was having one of my periodic attacks of insomnia a couple of nights ago, so at 4am I strolled out onto the patio, only to see that Orion the Hunter had arrived for a new season's hunting. He seemed to be threatening the Moon with his club, and so the Moon was hiding behind Taurus's head in the Hyades. I recorded the scene with my Sony DSC-HX60 compact camera. The images are composites of two exposures to avoid the Moon's glare washing out the stars.
Roger Samworth, Nuneaton

Picture praise

I hope all is well at *Sky at Night*. My son Lian and I love your magazine and he wanted me to send this picture to you as a token of appreciation.
Daniel and Lian Song, Kenya

Up in smoke

I was out imaging with my Celestron 6SE, Canon EOS 450D astro-modified camera and a 2x Barlow lens on Friday 6 September and took a close-up shot of the Moon at ▸

ON FACEBOOK

WE ASKED: What future space missions are you most looking forward to?

Phil Jones I think the exploration of moons such as Io, Europa etc, would be so exciting and fascinating. What about getting a lander on Pluto? That would put my head into a real spin!

Felix Hay The James Webb telescope for sure. The things it will send back will move our understanding forwards exponentially (I hope)

Rigs Brekne The one where they put me on a one man mission to the nearest inhabitable star system... lots of classical music to entertain me on the way. I'll explain to the locals how humans destroyed their own planet and decided to send one human to share our story.

Bruce Ashley Human colonisation of the Moon and Mars, and using Venus to mine hydrogen to use on Earth. That would impress me a lot!

Muhammad Abdullah Tariq Exoplanet hunters.

AR Gavin James Webb Space Telescope. It will be even more advanced than the Hubble Telescope and it will be able to image exoplanets, the first galaxies, see much further back in time in the history of the Universe and will greatly increase our knowledge of astronomy and cosmology.

SCOPE DOCTOR

Our equipment specialist cures your optical ailments and technical maladies

With **Steve Richards**

Email your queries to
scopedoctor@skyatnightmagazine.com

I have a Sky-Watcher 114mm Newtonian reflector and a Bresser 70/350 refractor. What is the best position to allow them to cool down properly?

ORLA SPEARS

It is very important to ensure that your telescope is at ambient temperature to achieve the best views as an imbalance of temperatures will result in disturbed air moving around in the optical tube, which will blur detail. To add to the problem, air temperatures usually continue to drop throughout an observing session so to some extent you will be chasing the ambient temperature downwards.

Different telescope designs cool down at different rates, with Newtonian reflectors cooling faster than refractors. The relatively large mass of the mirror in a reflector holds a lot of heat energy so blowing cool air over the mirror with a fan can help this to dissipate and some Newtonians have a cooling fan built in.

Warm air rises so to help it on its way, placing a Newtonian facing upwards and a refractor facing downwards – but with no diagonal or eyepiece in the focuser – is a good way of speeding up the cooling process.

▸ Keeping it cool: a Newtonian reflector should be faced upwards

Steve's top tip

What is a red dot finder?

Trying to locate objects directly through a telescope eyepiece can be quite difficult so it is normal to have a sighting aid installed on the telescope tube and aligned with the main optics. Historically, this has been a small, low magnification telescope known as a finderscope which gives a wide field of view to allow you to see when you are in the right part of the sky. However, in recent years, zero magnification finders that project an apparent target or small red dot on the night sky have become very common. These are known as 'red dot finders' and they have the advantages of producing their own illumination and being intuitive to use.

Steve Richards is a keen astro imager and an astronomy equipment expert

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19,202 (combined; Jan–Dec 2018)

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▸ 9:15pm. When I got home later in the evening I noticed that the single shot I took as I was re-focusing appeared to show some form of possible gas cloud or similar coming from the Moon. I initially dismissed it, but when I read that the Chandrayaan-2 lunar mission had crashed that night, I started to wonder if it may be connected. India lost contact with the craft at 20:08 UT time (9:08pm our time) and believe the craft crashed a couple of minutes later.
John Allen, via email

Though the timing is perfect, the craft's impact would have been much too small to resolve with an Earth-based telescope, even a large professional one. ***– Ed***

Making a night of it

Thank you to Tiffany Francis for her inspirational article on nightwalking (Field of View, October). It made me get up off my sofa, make a flask of tea and take a midnight stroll. I have never felt such pure pleasure at seeing the wonders of the night sky. Of course, take any precautions to stay safe. I didn't encounter any people at all – but saw quite a few bats and foxes! It truly was like viewing the world through a new lens. Nightwalking is the perfect way to tune in to the Universe and the beauty it has to offer, which is something I needed after a difficult few months. Earlier this year I was diagnosed with cancer. I'm one of the lucky ones for whom a cure was possible and I intend to grab every moment I can. It's given me a liberating sense of perspective and a fresh appreciation of being alive.
Stephanie Pedley, Bristol

Delighted to hear that Tiffany's article helped reaffirm your sense of wonder in our amazing place in the cosmos, Stephanie. ***– Ed***

Tweets

Robbie Carson
@Robbie_Carson • 13 Sep
Tonight's #moonrise of the 2019 #HarvestMoon. From what I've read it's been twenty years since the last #Fullmoon has happened on Friday 13th! @VirtualAstro @skyatnightmag @BBCStargazing

SOCIETY IN FOCUS

The late summer bank holiday saw the East Essex Astronomy Club in attendance at Quay Day, during Burnham-on-Crouch's week-long yachting regatta. Seven club members were on hand, offering visitors the chance to view the Sun through a selection of appropriately filtered telescopes.

The cloudless sky made for perfect solar observing conditions and over the course of the day around 150 visitors saw our star close up. Although the Sun is rather quiet at the moment, limb darkening and granulation were on view, and the waning Moon visible during daylight added to the show. Some visitors were also able to catch a glimpse of Mare Crisium on the eastern limb.

The East Essex Astronomy Club was formed in Burnham five years ago by Andy Hutcheon (the club's treasurer) and I. We now hold monthly meetings at the village hall, where talks are given on astronomical topics by members and guest speakers. We also have telescopes available to borrow. Our annual Introduction to Astronomy course will be held on Saturday 7 March 2020.
John Press, Chair, East Essex Astronomy Club
▸ facebook.com/groups/eastessexac

Sega Toys Homestar Flux

Satin Black

Imagine enjoying the sky full of stars while sitting on your sofa. This dream can become reality with the Sega Toys series of home planetariums.

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The indicated edges of a lunar crater surrounding the lens finish the look.

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www.segatoys.space 149GBP

Our pick of the best events from around the UK

WHAT'S ON

The rise of the Sisters

Carding Mill, Stretton, Shropshire, 23 November, 8pm–10pm

Enjoy a tasty bowl of soup accompanied by the astronomical knowledge of Pete Williamson, as you find out about the 'Seven Sisters' of the Pleiades open-star cluster.

https://bit.ly/2lSFOVn

Family astro party

Wimbleball Lake, Devon, 2–3 November

The Exmoor Dark Skies Festival comes to an end with a weekend of events. Saturday starts at 2pm with workshops, space experiments and storytelling, while Sunday's fun begins at 6.30pm with a stargazing stroll along the Barle Valley.

bit.ly/2lUm187

CAWAS 80th anniversary

Earlsdon Methodist Church Hall, Coventry, 8 November, 7.15pm

Light the candles and raise your glasses – it's Coventry and Warwickshire Astronomical Society's 80th birthday! Joining the celebrations will be Dr Nick Hewitt of the Royal Astronomical Society, who'll be lecturing on the Local Group.

www.covastro.org.uk

Transit of Mercury

Richmond Memorial Hall, Tomintoul, Moray, 11 November, 12.15pm

Mercury will pass across the face of the Sun on 11 November, something that happens only a few times every century – it won't happen again until 2032. Watch the event in style at the Cairngorms Dark Sky Park. See p30 for more information.

darkskies.glenlivet-cairngorms.co.uk

NATIONAL SPACE CENTRE X 4

PICK OF THE MONTH

▲ Good evening: the National Space Centre is marking the 50th anniversary of Apollo 12

Space lates

National Space Centre, Leicester, 16 November, 6pm

On 16 November, 50 years ago the crew of Apollo 12 was on its way to the Moon. Barely four months after the success of Apollo 11 in July 1969, NASA was sending another group of astronauts to explore and examine Earth's natural satellite.

The National Space Centre has a packed evening of after-hour Space lates events to commemorate the second Moon landing. Pop along to the Leicester venue and you'll get to hear what it was like guiding astronauts to the Moon from Pat Norris, a NASA navigation engineer who worked on the Apollo missions, as well as what it was like to cover the Moon landings from BBC analyst David Southwood. Representatives from NASA and ESA will also be attending to fill you in on how the agencies plan to return to the lunar surface.

You'll also be able to get your hands on meteorites and experience a Moon landing for yourself with the all-new CAPCOM GO! immersive show.

spacecentre.co.uk

Winterfest astro star party

Kelling Heath, Norfolk, 21–24 November

Birmingham Astronomical Society is organising this winter star party, a companion to its events in autumn and spring. Wrap up warm and prepare yourself for a weekend of stargazing.

www.winterfestastro.co.uk

Observe at Redoubt Fortress

Redoubt Fortress, Eastbourne, 30 November, 5pm

Join the Eastbourne Astronomical Society for an evening of observing. The event is free and you'll have a chance to try out a selection of the Society's equipment.

eastbourneas.org.uk

FIELD OF VIEW

Customising a DSLR for astro imaging

Avoiding the temptation to spend money on new kit, **Charlotte Daniels** stumbles onto the risky idea of DIY camera modification. But does it pay off?

Charlotte Daniels is an aircraft broker and journalist who recently returned to university to study physics. A long-time amateur astronomer, her interest in astrophotography began 18 months ago, having never owned a camera.

Astrophotography is an expensive hobby, especially for students. Having returned to university later than planned, I have acquired a decent setup on a budget, thanks to second-hand equipment. The urge to spend my student loan on a CCD and triplet apochromatic refractor remains, however I am generally happy with my DSLR camera and ED80 telescope. I know that there'll be 30 years between me and the 'dream' kit I'm saving for. I could afford it sooner, but only if I move into the cardboard box it arrives in.

In the meantime, I had been thinking of 'astro-modding' my Canon 700D – that is, removing the infrared (IR) blocking filter to allow the full spectrum of light to be captured. Seduced by the beautiful images posted in various social media groups, it didn't take much to convince myself that this adjustment was a wise move. I ran the risk of ruining my camera, but step-by-step instructions were easily available online. It was just too tempting.

And so one afternoon, armed with a set of minuscule screwdrivers and a scalpel, I set to work on my beloved camera. I had been warned by a couple of astrophotography pals that losing some of the tiny screws that held the camera together was inevitable, so I used an ice cube tray to house the items related to each step of the instructions.

Things went well until the first hiccup; a couple of screw heads had worn, making it impossible to remove the fascia. My partner, watching me dismantle the camera with the dexterity of a six year-old, told me not to move until he came back. Returning moments later with a hand drill, he removed the heads of the stubborn screws. Watching, I started to wonder whether this would backfire. Still, from then on, detaching cables and removing the filter was incident free.

Almost three hours later, the camera was reassembled with all removed screws accounted for. A clear night beckoned, and I headed out with my equipment. Ninety minutes of the Heart Nebula, NGC 896, yielded promising improvements – as well as worrying observations. While nebulosity was enhanced, I had substantial light leak creeping into the images. Increased sensitivity meant that external light was affecting the frames – even from the LED light emitted by the camera during an exposure. To address this, I had to cover the viewfinder and LED light, and close the LCD screen while the camera was imaging. The same applies when taking dark frames.

Cloaking ritual performed, I slewed to the North America Nebula, NGC 7000, for 190 minutes. I was impressed and relieved – the improved quality of the images meant I didn't need to worry about over-stretching or -processing the data. As autumn and winter skies approach, I'm looking forward to what can be achieved once the Horsehead Nebula emerges.

This modification will keep me happy for the season, as I learn just what can be achieved with the re-engineered camera. Was it worth it? Absolutely, though of course I am saying that because the gamble paid off. Perhaps a hydrogen-alpha filter is on the horizon.

ELENI DEBO/FOLIO ART

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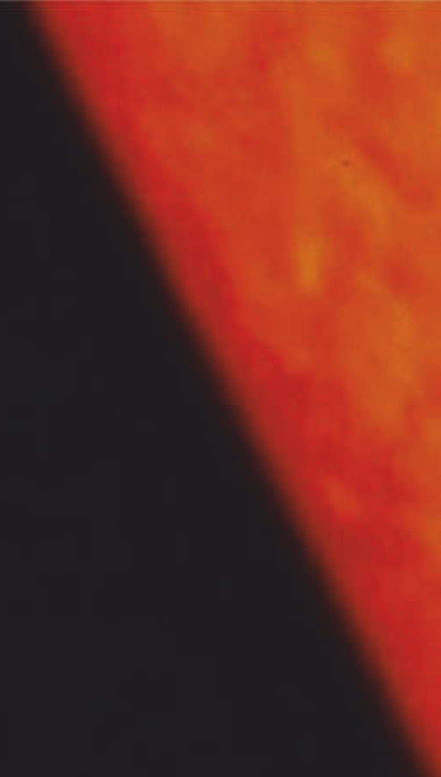


Close encounter: Mercury passes in front of the Sun, as captured on 8 November 2006 by the Hinode Solar Observatory

A messenger ON THE MOVE

CAUTION
Never observe or image the Sun with the naked eye or any unfiltered optical instrument

On Monday 11 November 2019 the tiny planet Mercury will pass between Earth and the Sun. **Jamie Carter** looks at how, why and where to observe this rare event

To the Romans, the planet Mercury was Mercurius, the messenger of the gods. To modern astronomers, it's the smallest, hottest and fastest-moving planet in the Solar System, and the one that's nearest to the Sun. Rarely glimpsed by sky-watchers because it's usually lost in the Sun's glare, Mercury will nevertheless provide one of the most arresting celestial sights of 2019 when, on Monday 11 November, it will pass across the face of the Sun. It's an event that's among the rarest of predictable astronomical phenomena.

From Earth, only Mercury and Venus, the two innermost planets in the Solar System, can be seen to transit the Sun's disc. For observers in the UK the event will begin around 12.35pm and continue past sunset, at around 16.22pm. Even though the UK won't get the best view of the event, it will be well worth trying to observe it through a solar telescope, not least because you don't need to witness the whole thing; a short observation will do (and with 75 per cent chance of cloud cover in mid-November that's probably a realistic goal). But also because it won't happen again until 13 November 2032.

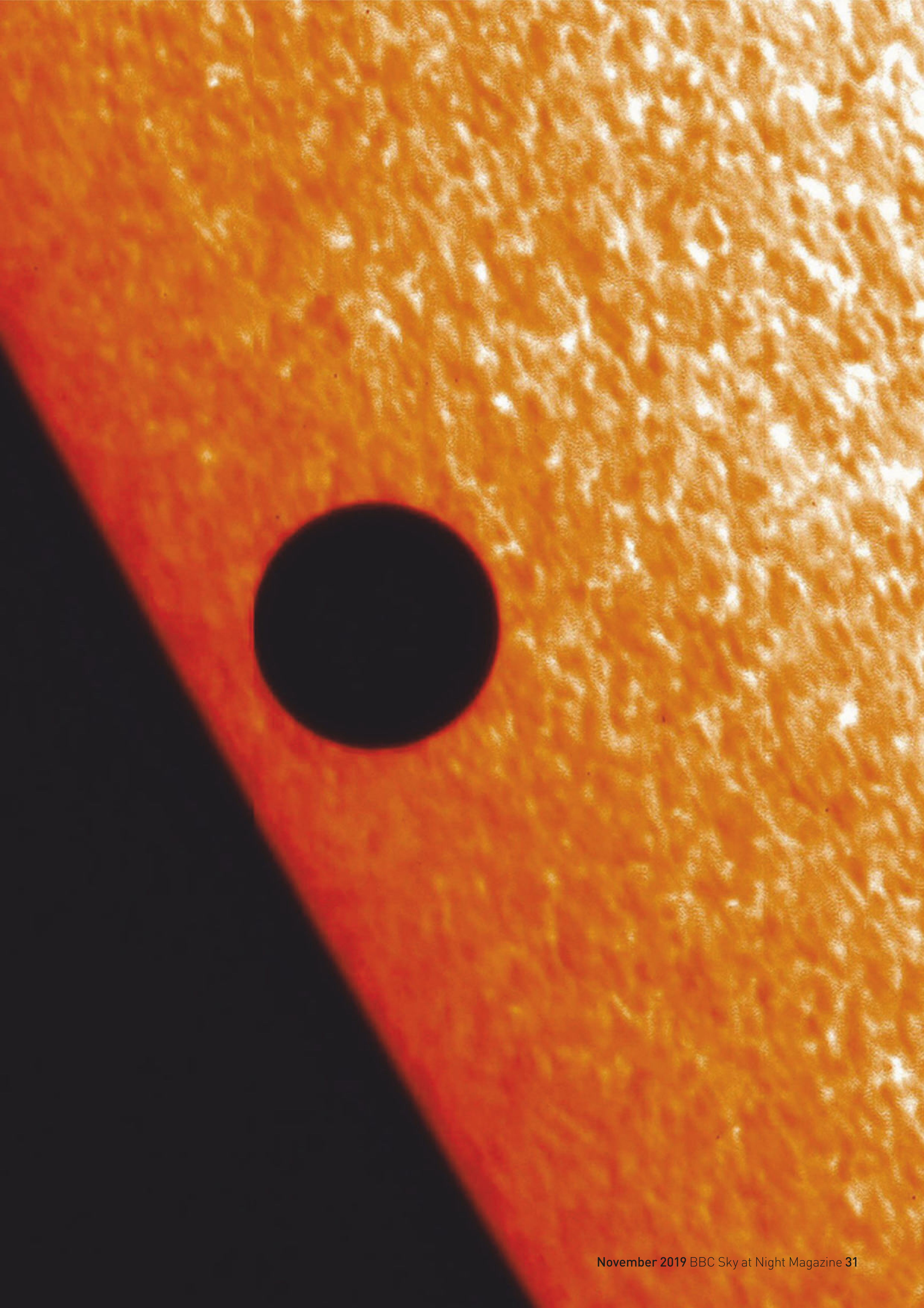
Of course, Mercury's trip across the Sun isn't the only transit we get to see. A more famous event is the transit of Venus, an event that last occurred in 2012. But even if you consider the transit of Mercury to be a smaller and less impressive affair, it's something of a moot point since the next transit of Venus doesn't take place for another 98 years. Besides, observing the transit of Mercury can be just as rewarding.

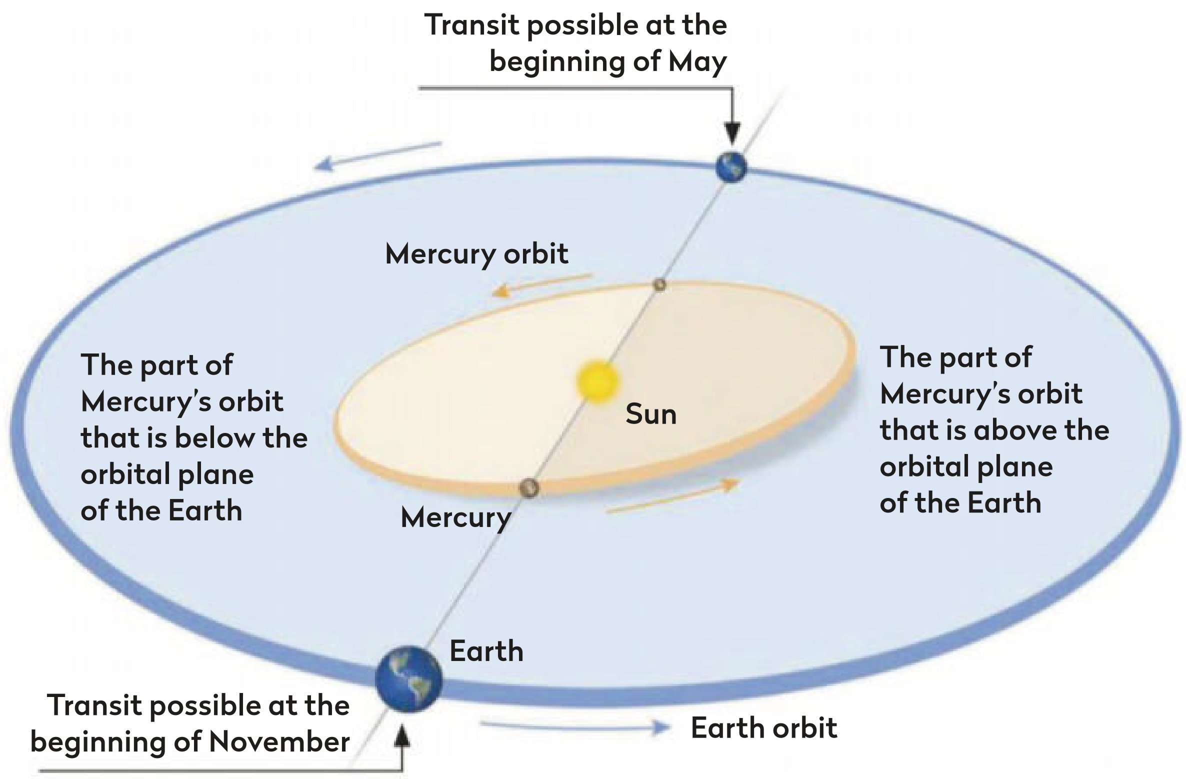
Starting small

"I thought it was going to be a very small dot because Mercury is 1/150th the diameter of the Sun, and I thought there was no way I would see it with my three-inch refractor," says Eric Emms, an amateur astronomer and member of The Baker Street Irregular Astronomers in London, who observed a previous transit. "I was surprised at how ▸

Jamie Carter is a well-travelled amateur astronomer and author of *A Stargazing Program for Beginners: A Pocket Field Guide*

HINODE JAXA/NASA/PPARC





▲ A diagram of Mercury's orbital tilt relative to Earth. Since Mercury's orbit is inclined 7° to Earth's, it intersects the ecliptic at two points

ILLUSTRATION BY PAUL WOOTTON, WILL GATER, KRISTINA BLOKHIN/ALAMY STOCK PHOTO

▸ big and dark its disc was as it moved across the surface of the Sun – it was amazing!"

Xavier Jubier, an eclipse-chaser from Paris, France and a member of IAU Working Group on Solar Eclipses found another way to view Mercury's last solar transit. "It's actually visible to the naked eye with solar eclipse glasses," he says. "Although the apparent diameter of Mercury is much smaller than Venus, which means that without enough magnification it's more difficult to observe." He recommends using a telescope with a focal length of 1,000mm, though any smaller telescope will get you a view of Mercury as a tiny black dot. "Simple and inexpensive solar scopes can also be used," he says.

Telescopes have been pointed at transits of Mercury for centuries, including those at the Royal Observatory Greenwich in London. "If you can make very accurate timing observations of the transit of Mercury it can help you to calibrate Mercury's orbit and calculate the size of the Solar System," says Tom Kerss, an astronomer at the Royal Observatory Greenwich. Mercury's orbit is inclined about 7° to the plane of the ecliptic, the Sun's apparent path during the year against the background of stars, as seen from Earth.

It was Albert Einstein who finally figured out why Mercury's orbit didn't entirely conform to Newton's laws of motion: the Sun's effect on the local space-time causes the tiny planet to accelerate as its orbit brings it close to the star. But long before Einstein's Theory of Relativity solved the mystery, it was Edmund Halley, who succeeded John Flamsteed as the Astronomer Royal at Greenwich in 1720, who highlighted the importance of transits of Mercury after observing one from St Helena in 1677.

"Halley wrote papers explaining how the transits of Mercury could be used to calculate the distance between the Sun, Earth and Mercury, and the scale of the Solar System," says Kerss. "It's how things like the orbits of Neptune and Uranus were determined long before the days of computers – so Mercury is very useful in that regard because it's such a frequent transiter."

Looking ahead

Given how many transits of Mercury have now been observed, you'd be forgiven for thinking there's not much left for us to learn from them. But that's not the case. "We can use transits of Mercury to calibrate

A century of transits

On average, there are a couple of transits of Venus per century, but 13 or 14 transits of Mercury over the same period. What's more, transits of Mercury always occur in May and November. What makes them so oddly regular? "It's to do with the eccentricity of Mercury's orbit and the resonance it has with Earth's orbit," says Kerss.

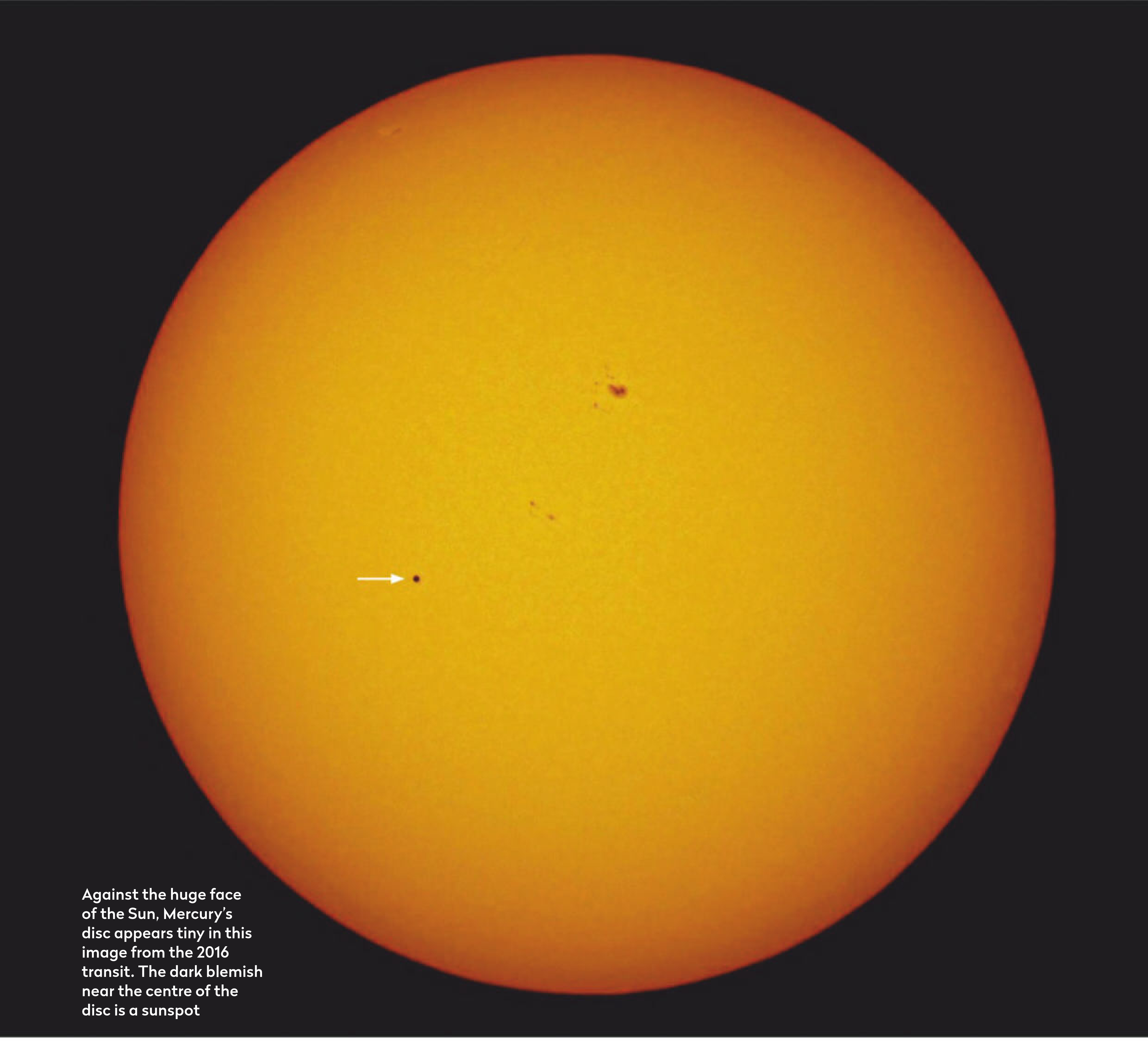
Mercury's apparent size changes by up to 20 per cent and that's a function of it having the Solar System's most eccentric orbit. "When we see a transit of Mercury in May, it's while Mercury is closer to Earth and so it has a 12 arcsecond disc," says Kerss. "In November, the transits occur when Mercury is closer to the Sun so the planet appears slightly smaller from our perspective, about 10 arcseconds."

At 88 days, Mercury's orbit of the Sun is almost a quarter of that of Earth, which means it's close to being in orbital resonance with Earth, hence the transits occur at the same times of year... for the time being. "The timing between them will drift and though they occur in May and November now, that will change in centuries to come," says Kerss. "But they'll always be six months apart."

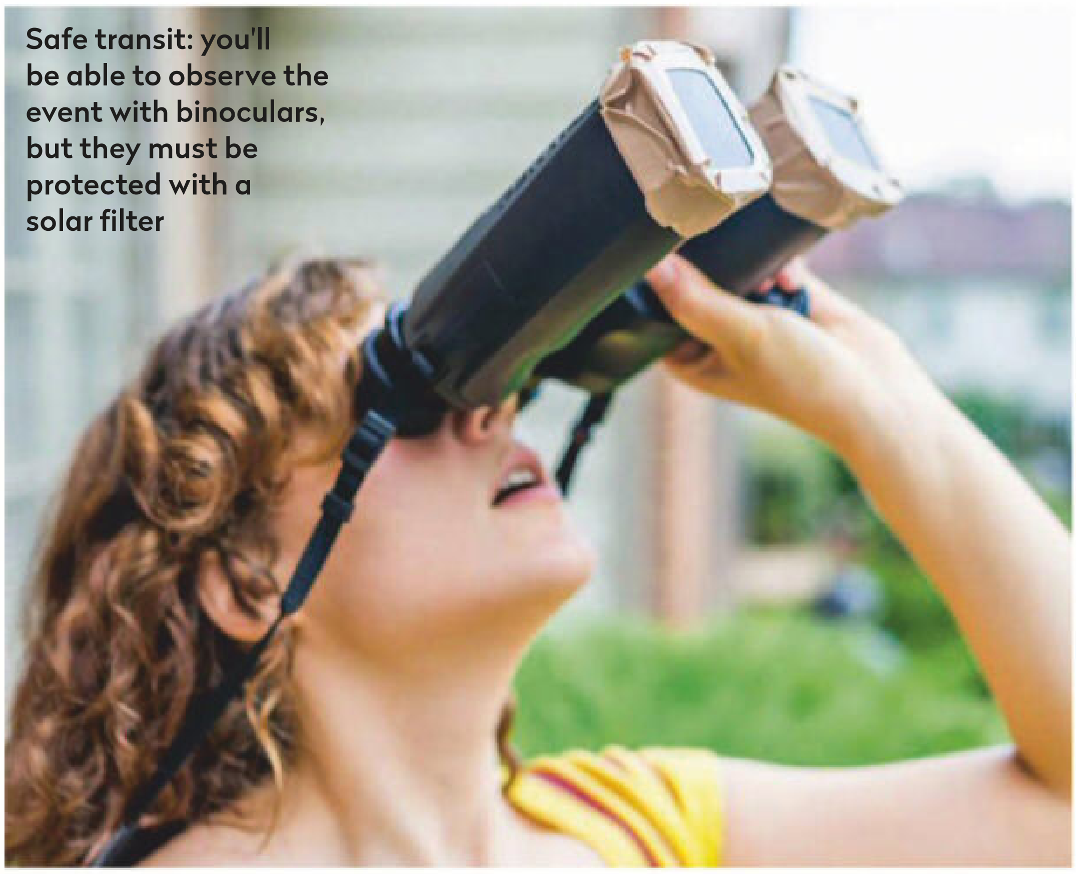
MERCURY TRANSITS 2001–2100

DATE	UNIVERSAL TIME	SEPARATION*
7 May 2003	07:52	708"
8 Nov 2006	21:41	423"
9 May 2016	14:57	319"
11 Nov 2019	15:20	76"
13 Nov 2032	08:54	572"
7 Nov 2039	08:46	822"
7 May 2049	14:24	512"
9 Nov 2052	02:30	319"
10 May 2062	21:37	521"
11 Nov 2065	20:07	181"
14 Nov 2078	13:42	674"
7 Nov 2085	13:36	718"
8 May 2095	21:08	310"
10 Nov 2098	07:18	215"

*distance (in arcseconds) between the centres of the Sun and Mercury



Against the huge face of the Sun, Mercury's disc appears tiny in this image from the 2016 transit. The dark blemish near the centre of the disc is a sunspot

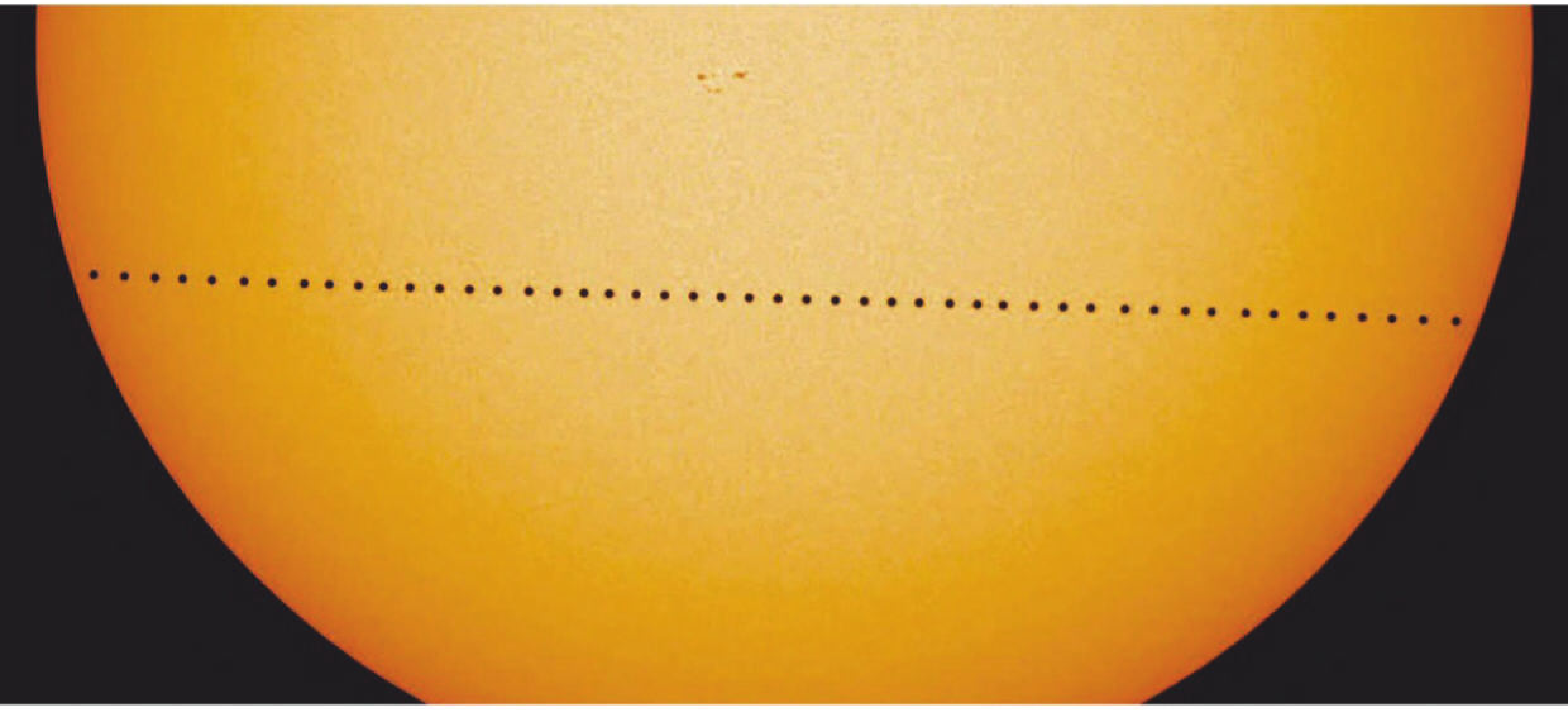


Safe transit: you'll be able to observe the event with binoculars, but they must be protected with a solar filter

our understanding of what exoplanet transits may look like to our instruments," says Kerss.

Astronomers interpret a dip in brightness of a star as a successful discovery of an exoplanet and have recently moved on to try to detect exomoons. Mercury doesn't have any moons (as discovered by astronomers at the Royal Observatory during a transit back in 1914) so light curves from a transit give astronomers a template of what an exoplanet looks like when it doesn't have any moons.

Professional astronomers will therefore be collecting data from this month's transit of Mercury, but it's a relatively simple sight for any amateur astronomer or stargazer to watch safely. "Obviously you can't look at the Sun with normal binoculars or telescopes," says Eric Emms. "In 2016, I used a three-inch refractor and made a solar filter to put over the objective lens using an A4 sheet of Baader AstroSolar film, which costs about £20." The same can be done for binoculars. "8x45 binoculars should still let you see Mercury as a dot," says Emms. ▸



▲ When Mercury last passed between the Sun and Earth, on 9 May 2016, the event was captured by NASA's Solar Dynamics Observatory

▸ With the solar filter film in place, it's then simply a case of aiming your instrument at the Sun, which from the UK will be at about 20° high in the southwestern sky when the transit begins. That's relatively low, but it's also a comfortable height to observe. It's a moving target, of course, but that doesn't mean you need a lot of expensive equipment. "I just manually tracked using a cheap manual altazimuth mount," says Emms. "I didn't use a computer-controlled solar tracking mount, though astrophotographers would have to use an equatorial mount with a solar drive on it." If you're using binoculars, however, you should consider using a tripod, though there is an even cheaper option. "The old-fashioned way is to lean on an upturned broom to keep your binoculars steady," says Emms, who is planning to observe from London's Regent's Park.

If you're willing and able to travel far – whether it's for clear skies or to see the entire transit (or both) – there

Measuring the Solar System

▲ Transit observers, like those who gathered in 2012 for Venus, will take part in a wider Citizen Transit of Mercury project across the US

Transits of both Mercury and Venus can be used to measure the distance between Earth and the Sun; the Astronomical Unit (AU). The mathematical basis for this is the solar parallax effect you get from observing a transit of one of the planets from different locations on Earth's surface and seeing how much the planet's position appears to vary against Sun's disc at a particular moment. Then, using some simple triangulation trigonometry, you can calculate the distance from Earth to the Sun.

The Citizen Transit of Mercury (ToM) project is an attempt to do the same during Mercury's transit this month, ostensibly to teach school kids how to calculate the size of the Solar System using observations and some fairly basic maths. "We're going to have about 20 observing sites spread as far apart as we can and everyone will use identical equipment to take simultaneous images of Mercury during the transit," says Zack Stockbridge, astronomy educator at the American Museum of Natural History and maths teacher at Southwestern Community College in Sylva, North Carolina who's coordinating the project. "That keeps the solar diameter the same to within just a few pixels in all the equipment, so we don't have to deal with resizing things."

The students will take short video clips and then stack them into single-image files. "Having multiple sites widely spaced and perfectly synchronised will allow us to see the parallax effect and see Mercury's disc shifting positions on the Sun," says Stockbridge. "We're going to produce 1,536 x 1,536-pixel images and Mercury is only going to shift possibly less than 10 pixels in the image. It just depends on how far the sites are spaced; the closer they are the smaller the shift."

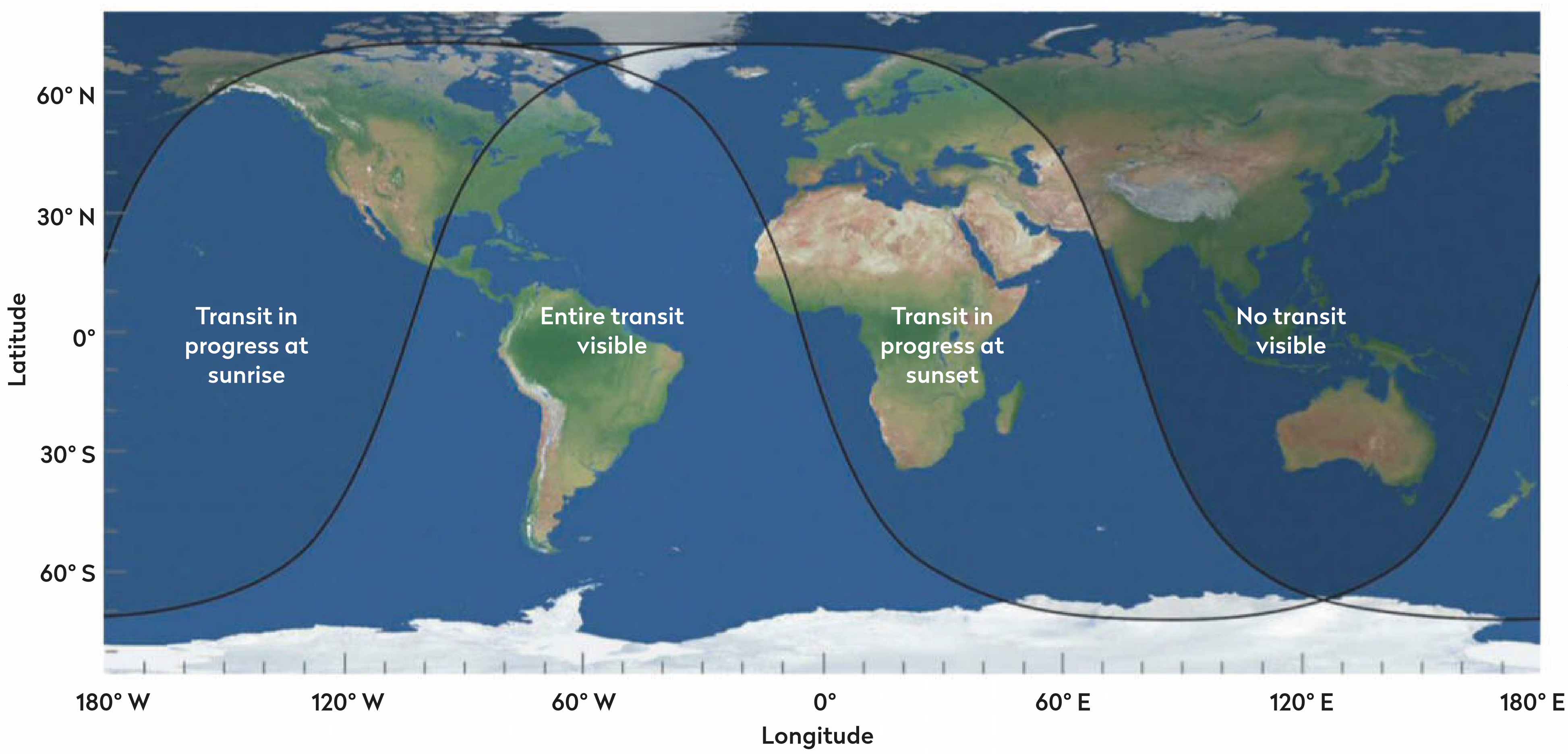
Mercury's disc sits silhouetted against the limb of the Sun, as our star's roiling surface provides a dramatic backdrop

▲ **Be sure to use a specialist, certified solar filter – following the manufacturer's instructions – when observing and imaging the transit**

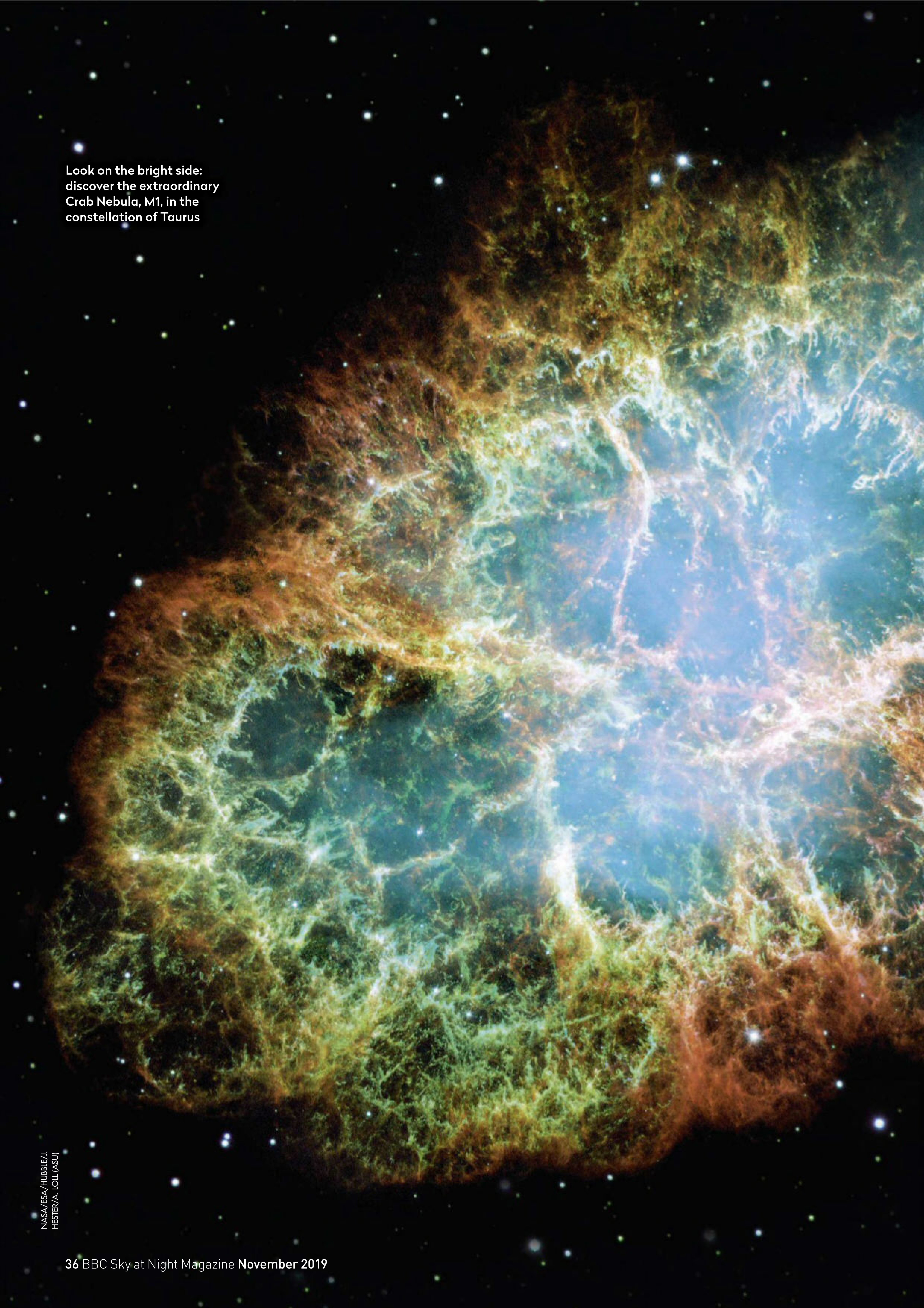
are some favoured locations. "I prefer to not view it from France because the transit will be in progress at sunset and the weather in November is not great," says Jubier, who plans to be at the El Leoncito Astronomical Complex in Argentina. "Conditions for observations aren't really optimal, which is why I have opted for Argentina where the whole transit is visible and there are good prospects of clear skies." In Argentina, the transit occurs when the Sun is higher in the sky with better seeing likely than Europe. The same goes for the Atacama Desert in northern Chile and the Canary Islands, though all of South America and eastern USA will get to witness the entire transit.

You don't need to travel to see it, though, and unless you plan to take astronomical measurements, there's no need to observe the entire event. With a simple and safe setup and a bit of luck with the weather, it will be possible to watch Mercury move across the Sun's face – a sight any astronomer won't want to miss.

► ***For further details on observing and imaging the transit of Mercury see pages 48 and 76***

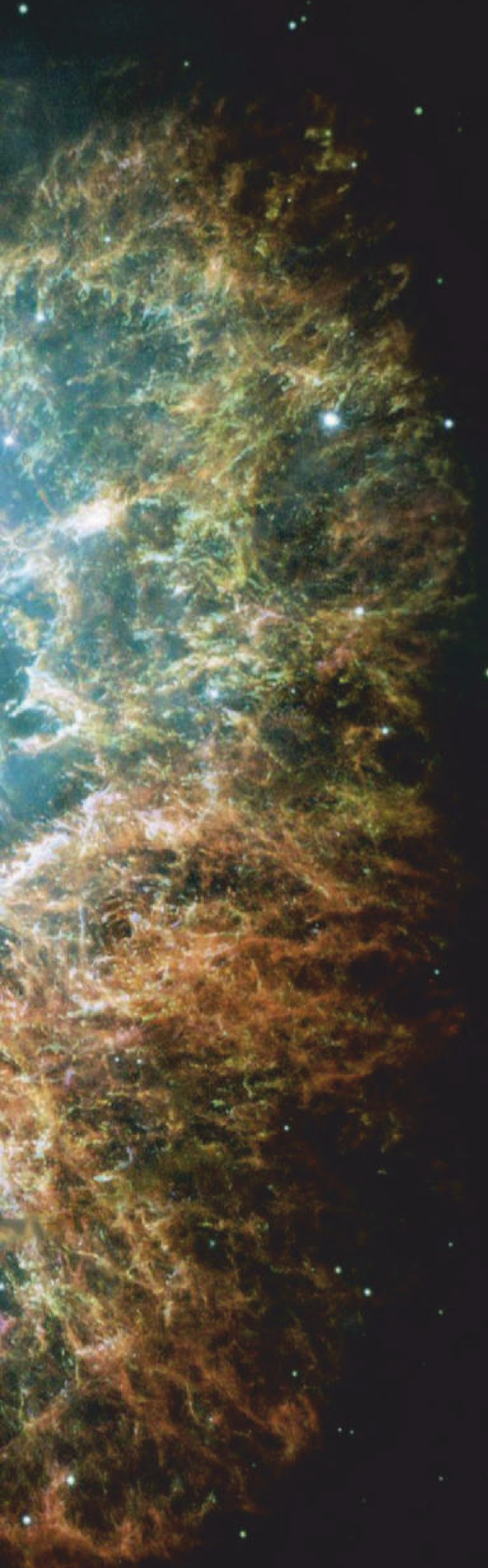


▲ **A global visibility map of the Mercury transit (11 Nov) shows South America and eastern USA are best for observing the entire event**



Look on the bright side: discover the extraordinary Crab Nebula, M1, in the constellation of Taurus

NASA/ESA/HUBBLE/J. HESTER/A. LOLL (ASU)



Fireworks OF THE NIGHT SKY

Callum Potter reveals the big explosions to be seen in November's skies – the vast remnants of ancient supernovae

As Bonfire Night approaches it's a great time to take a look at some of the biggest bangs in the Universe – supernovae. There hasn't been a visible supernova in our Galaxy since 1680, but we can see their remnants – the gas and dust left behind in their wake. Often diffuse, with wispy strands of nebulosity, supernovae remnants can be among the most challenging targets for the visual observer.

The 5 November itself is probably not the best time to chase after these targets, as the smoke from bonfires and firework displays will fill the sky with haze. This year, the Moon will be around its first quarter, making these faint objects even more difficult to see, so you will have to wait until after it sets at around midnight (if the smog has cleared). Seeing all these remnants in one night is a tall order, so it may be worth trying to observe them through the month – from 1 November when the Moon sets earlier in the evening. To improve your views make sure you choose a site away from direct light sources, though there are a few objects that should be visible from suburban skies.▸

Callum Potter is the current president of the British Astronomical Association, and director of the deep-sky section.

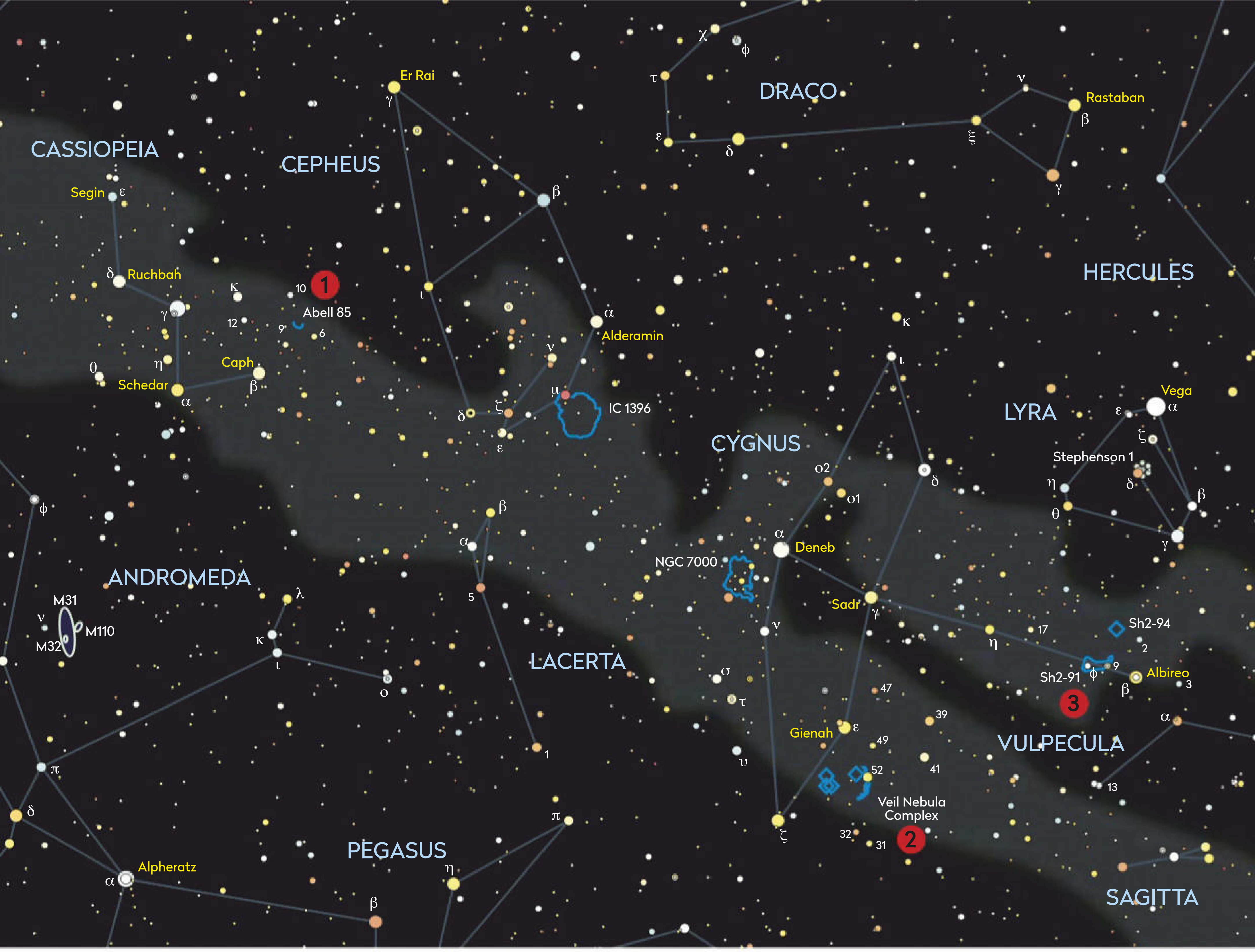
Geared up!

Our targets here are varied and no single scope is ideal for all. Naked eye, binoculars and small and large scopes all have their role. Narrowband 'nebula' filters pick out specific colours that the nebula shines in. The OIII filter picks out light emitted by oxygen and is in the green area of the spectrum. Also try UHC (Ultra High Contrast) filters; these select broader OIII lines and hydrogen-beta wavelengths in the blue-green part of the spectrum.

▲ **Nebula spotting: the author's DSLR camera is attached to a star tracker and a sturdy tripod**

A DSLR camera is good for imaging larger objects, but essential accessories include a star tracker and a tripod so you can take exposures of many minutes without picking up star trails. Polar align your scope, then take multiple images and stack with an image-processing programme. A DSLR that's had its infrared filter removed can also pick up the red light of hydrogen alpha.

Remember, even with a regular camera you should be able to image a nebula.

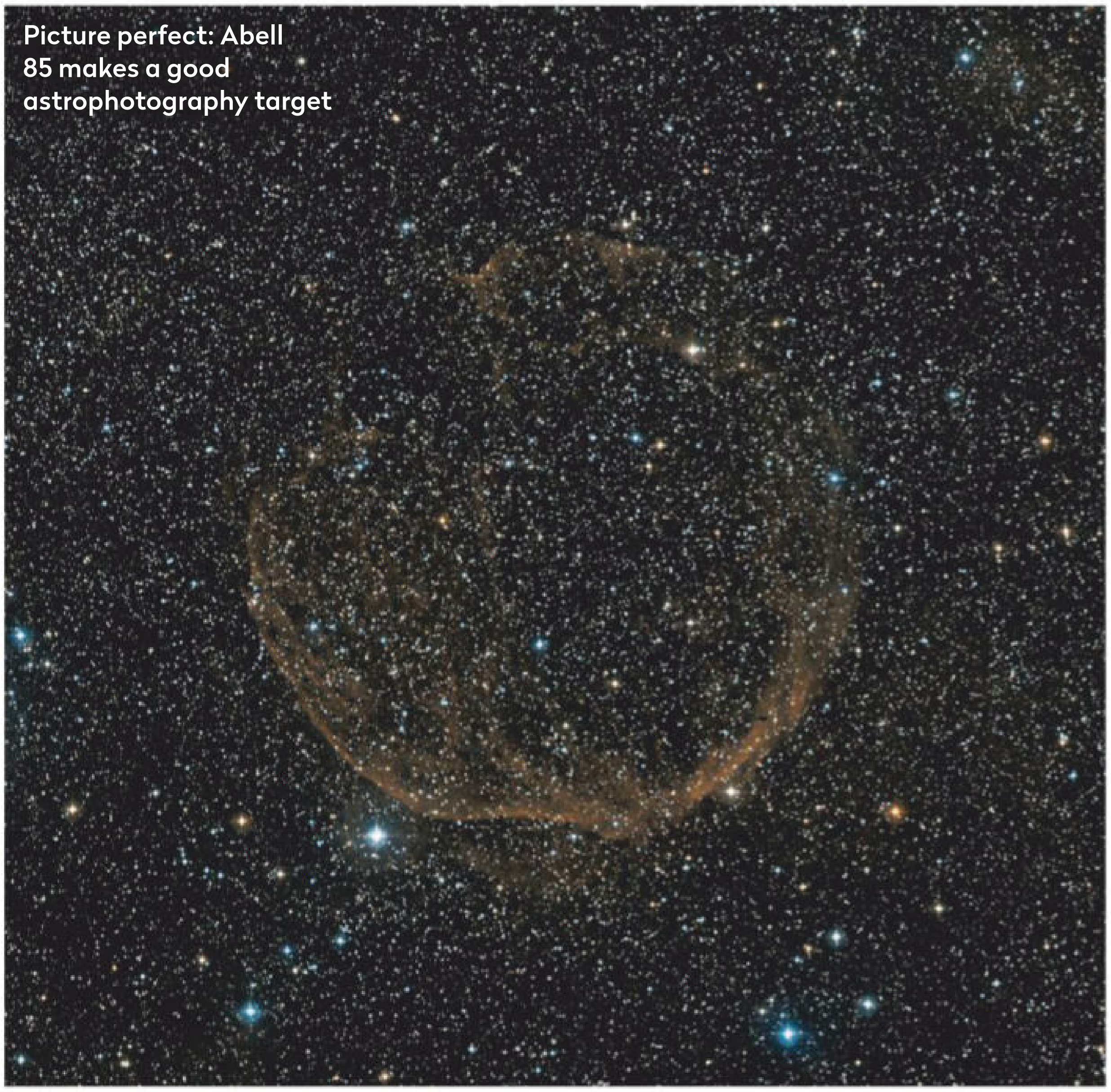


Abell 85 ▷

1 Abell 85, also known as CTB1, is an exceedingly difficult object for visual observers.

Originally it was thought to be a planetary nebula (a roughly spherical cloud of gas around a dying star), which George Abell listed in his catalogue. But further research showed this object to be a genuine supernova remnant.

Abell 85 is located in Cassiopeia, a short hop 3.5˚ north of Caph (Beta (β) Cassiopeiae). It's about 0.5˚ in diameter – the size of the full Moon. It predominantly emits in red hydrogen-alpha light, at the red end of the spectrum, and is quite weak in bluer OIII and hydrogen-beta emissions. This makes it difficult for visual observers as our dark-adapted eyes are not very sensitive to the deep red. If you have a very large telescope (16-inch aperture or more) and favourable sky conditions, give it a try. Abell 85 is a good target for CCD imaging, however.



Picture perfect: Abell 85 makes a good astrophotography target

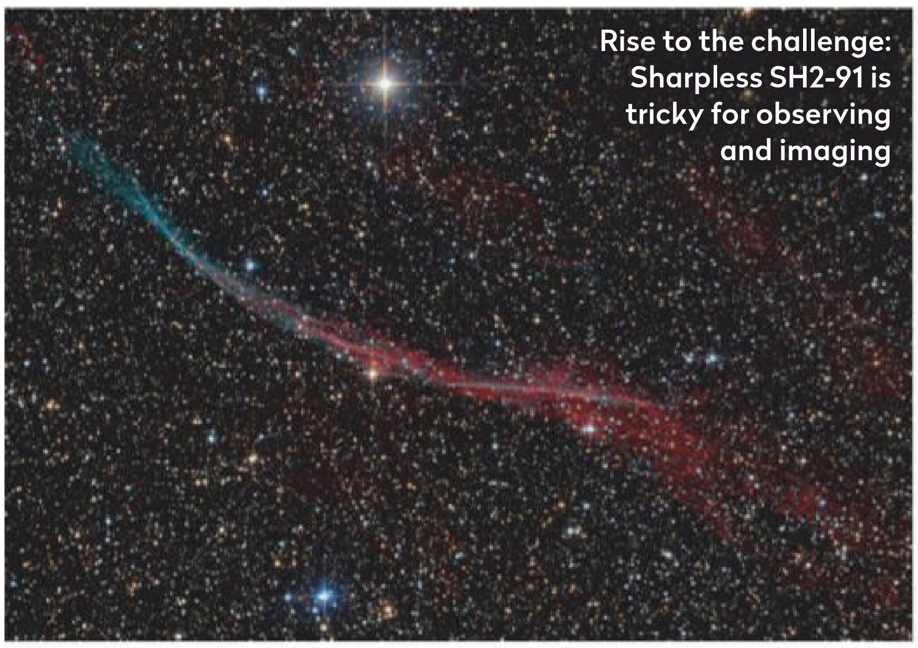
CHART BY PETE LAWRENCE, DAVIDE DE MARTIN/SCIENCE PHOTO LIBRARY, THOMAS HENNE/ CCDGUIDE.COM, TOMMY NAWRATIL/CCDGUIDE.COM, CAPPAN/ISTOCK/GETTY IMAGES

Veil Nebula ▷

2 One of the most beautiful nebulae, the Veil, used to be considered a really challenging object, but these days it is routinely observed with small telescopes such as 3-inch (76mm) refractors. The game changer for viewing the Veil has been the nebula filter, and the OIII is particularly useful in this case.

There are two brighter sections of the Veil Nebula, the eastern side, NGC 6992, and the western side, NGC 6990, which is also known as the Witch's Broom. To find the western Veil it's easiest to locate the star 52 Cygnii, which is embedded in the Broom. From here you can track around the nebulosity to the north and east to find the eastern section. The Veil is really big on the sky – with a diameter that measures about 3°, equivalent to six full Moon widths. The nebula lies about 2,100 lightyears away and has a real diameter of about 110 lightyears. The supernova that spawned this remnant exploded about 8,000 years ago.

Beauty spot: use a nebula filter to reveal the splendour of the Veil



Rise to the challenge: Sharpless SH2-91 is tricky for observing and imaging

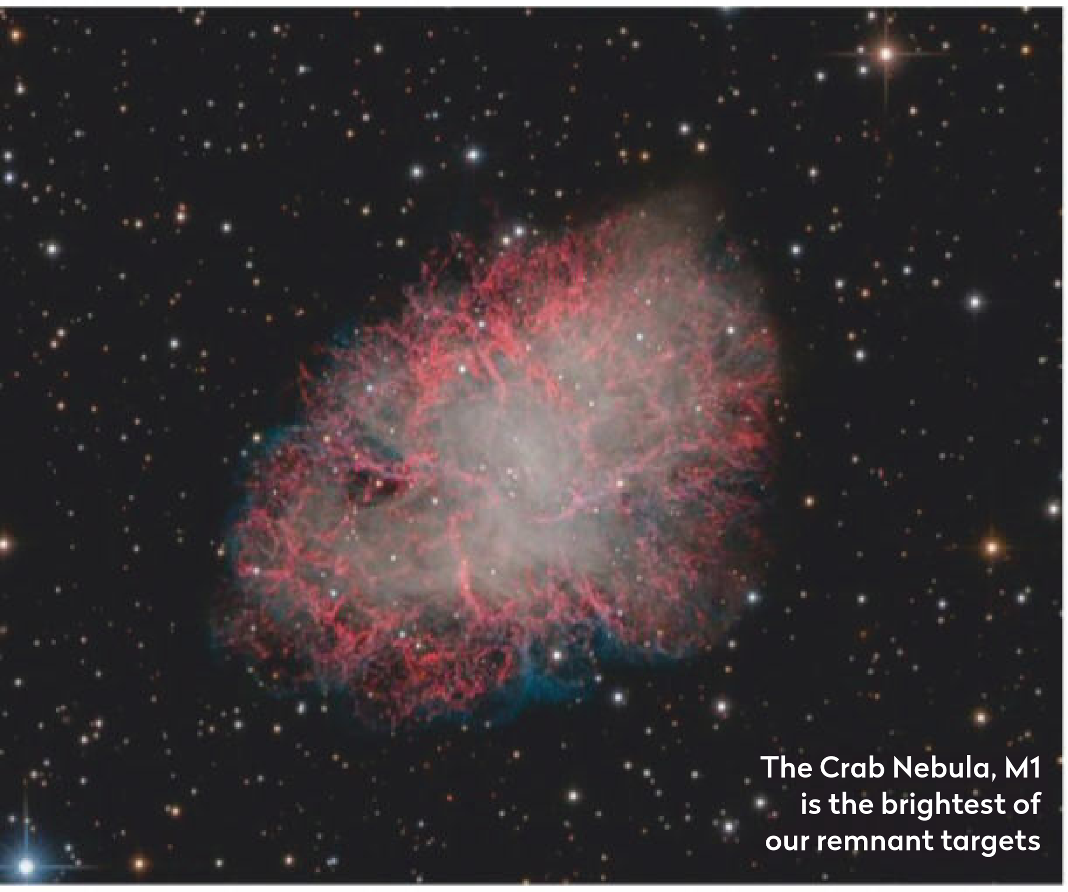
Sharpless SH2-91 △

3 Sharpless SH2-91 is the brightest of a number of filaments that make up the 'other' Cygnus supernova remnant. It's quite a lot fainter than the Veil and will be a big challenge for most observers. A large telescope with a 12-inch (304mm) aperture or more and nebula filters will help to see it. The supernova that created this remnant exploded about 30,000 years ago and lies about 2,500 lightyears away from us. To find SH2-91, start out at the beautiful double star Albireo and travel up the neck of the swan to Phi (ϕ) Cygnii – then move 12 arcminutes to the south to find an 8th magnitude star; the brightest part of the filament is centred around this star. This filament extends about 20 arcminutes. SH2-91 is an under-observed object, both visually and by imagers; if you're up for a challenge, give it a go. ▸

What is a supernova remnant?

A supernova remnant is the material of a star that's ejected into space when it explodes. There are two main ways in which a star can become a supernova. One is when a big star nearing the end of its life, having burned all its fuel, collapses in on itself, with the inrush of material rebounding off the star causing it to explode. The same process can happen in a binary star system when a high-mass, white dwarf star collects material from a companion red giant star. Once a critical mass is attained, the white dwarf becomes a supernova.

When the star explodes all the material that made it up is expelled into interstellar space at high speed. It heats up and the shockwaves end up creating the structures we can see through our scopes. Most of the heavy elements in the Universe are created during these explosions. Over time the nebulae will dissipate, so all the supernovae remnants we can see are comparatively young. This material eventually re-cycles into new stars and the cycle continues.



The Crab Nebula, M1 is the brightest of our remnant targets

Crab Nebula, M1

4 The Crab Nebula, also known as M1, is the first object in Charles Messier's catalogue of comet-like objects that aren't actually comets. Although Messier found it in 1758, M1 had previously been noted by John Bevis in 1731, and the supernova which created the remnant was observed by Chinese astronomers in AD 1054. It came to be known as the Crab Nebula following sketches made by Lord Rosse at Birr Castle.

M1 is the brightest of our targets at mag. +8.4, but is also quite small with a diameter of around 6x4 arcminutes. Located in Taurus it's quite easy to find in a small telescope or binoculars. If star-hopping, start at Zeta (ζ)Taurii and nudge just a degree or so northwest, and you should alight nicely. Being compact it stands out quite well, and it's easy to see why it might be confused with a comet.

An interesting experiment is to compare old astrophotos of the Crab with recent images – when these are aligned you can see the nebula's expansion.

Take time observing the Jellyfish Nebula and you may glimpse its tendrils

Jellyfish Nebula

5 Popular with imagers, the Jellyfish Nebula is also a good target for visual observers. The reason for its 'jellyfish' moniker is more obvious in pictures than during visual observing. It lies in the constellation of Gemini so you can find it by first locating the star Eta (η) Geminorum, which marks the foot of Castor. Then it's just three quarters of a degree or so east to land on the nebula. You will need a scope with an 8-inch (203mm) aperture and a nebula filter; an OIII is usually a good one for this. The Jellyfish is nearly a degree in diameter. Visually the curve of the nebula which makes up the body of the 'jellyfish' is the most prominent feature. Take time to observe, though, and some of its tendrils may come into view. It lies about 5,000 lightyears away and estimates of its age range from 3,000 to 30,000 years.

The Witch Head

6 The Witch Head looks like a reflection nebula so it might come as a surprise to realise it is actually a supernova remnant lying about 900 lightyears away. The remnant is very old and rather than being illuminated as a result of the supernova explosion, it is shining by the light of the bright blue giant star Rigel. It lies in the constellation of Eridanus close to Orion. Rigel is the best starting point if you are trying to seek out the nebula; just hop 2.5° north-east and you should be there. It is large and diffuse which makes it difficult to pick out, but small telescopes such as a 3-inch (76mm) refractor with low power wide-field eyepieces can reveal it. However, our trusty narrowband filters will be of no use – reflection nebulae are principally blue with no peaks in the OIII or hydrogen-beta regions.

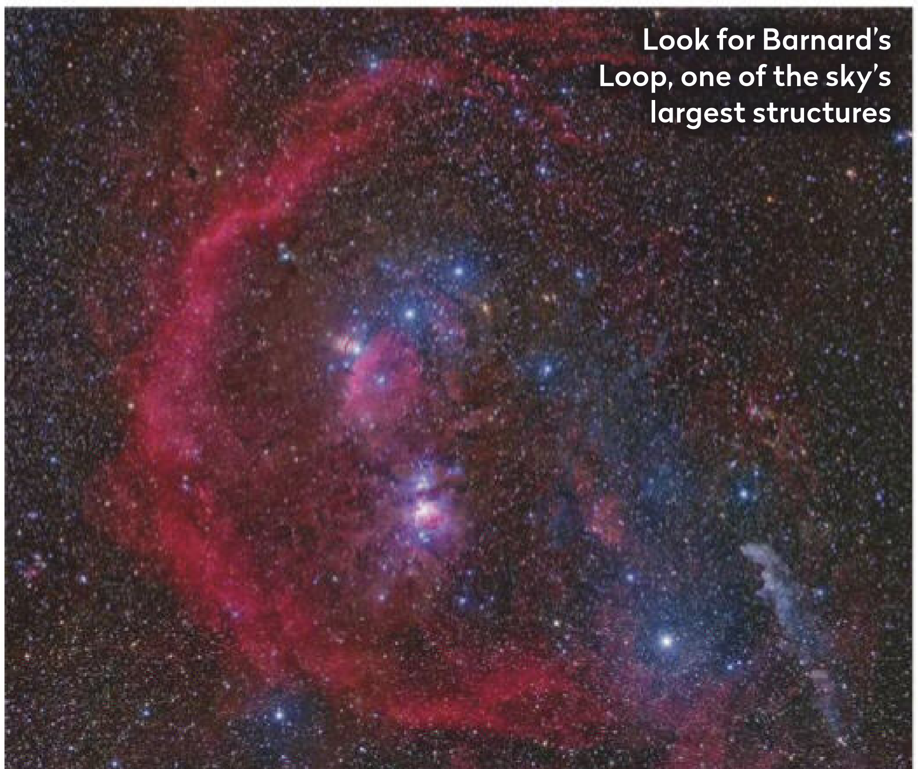
The creepy Witch Head reflects the light of the blue giant star Rigel

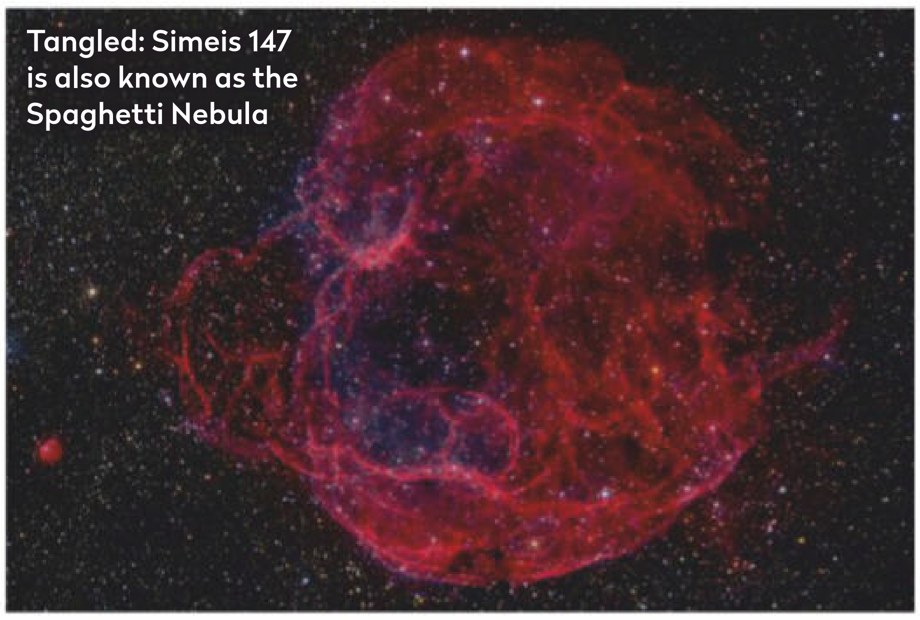
Barnard's Loop ▽

7 Barnard's Loop, which circles Orion, is a straightforward target for astrophotographers, but a challenge for visual observers. Probably one of the largest structures on the sky, its huge arc covers about 10° and it might come as a surprise to realise this object is a supernova remnant. Its distance is rather uncertain, but it's nearby, in the region of 500 to 1,400 lightyears away, making it something like 100 to 300 lightyears in diameter.

Good deep-sky observing conditions will be essential for any naked eye view, and only the brightest portion to the south of the star 56 Orionis will be visible. Zero power, or low power (x2), binoculars can help to keep your attention focused on one area and can be equipped with nebula filters (UHC) to assist further.

With Orion prominent in the sky all winter there will be plenty more observing opportunities as the season progresses.


Look for Barnard's Loop, one of the sky's largest structures


Tangled: Simeis 147 is also known as the Spaghetti Nebula

Simeis 147 △

8 Simeis 147 was discovered at the Simeis Observatory, an outpost of the Crimean Astrophysical Observatory, in the 1950s. They were photographing the night sky looking for HII regions (a volume of space where the hydrogen is in an ionised rather than neutral state) and catalogued these in their Bulletin. Most of the objects were already known with NGC numbers or other designations, so not many are known by their Simeis number. Simeis 147 is one of the most interesting supernova remnants; its loops of nebulosity lead to its common name of Spaghetti Nebula.

Simeis 147 lies in Taurus near to the Auriga border, and is about the same size as the Veil Nebula, 3° in diameter. However, it is much fainter and a much bigger challenge for the visual observer. A scope of 16-inch (406mm) aperture or more may be needed, but it's not so hard to image and shows up well in hydrogen-alpha.

CHART BY PETE LAWRENCE, BERNHARD HUBL/CCDGUIDE.COM X 2, BLACKPHOBOS/ISTOCK/ GETTY IMAGES, JOHANNES SCHEDLER/CCDGUIDE.COM, TOMMY NAWRATIL/CCDGUIDE.COM

BBC Sky at Night MAGAZINE

16-PAGE CENTRE PULLOUT

The Sky Guide

NOVEMBER 2019

TRANSIT OF MERCURY

Observe the innermost planet as it crosses the Sun's disc

PEAK PRACTICE

Find the best time to spot the Leonid meteor shower

JUPITER BY DAY

Catch the daylight lunar occultation of the gas giant

PETE LAWRENCE

About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four

Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month...

✦ Asteroid 4 Vesta reaches opposition
✦ Observe the lunar crater Lalande
✦ We challenge you to capture a stunning sunset

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

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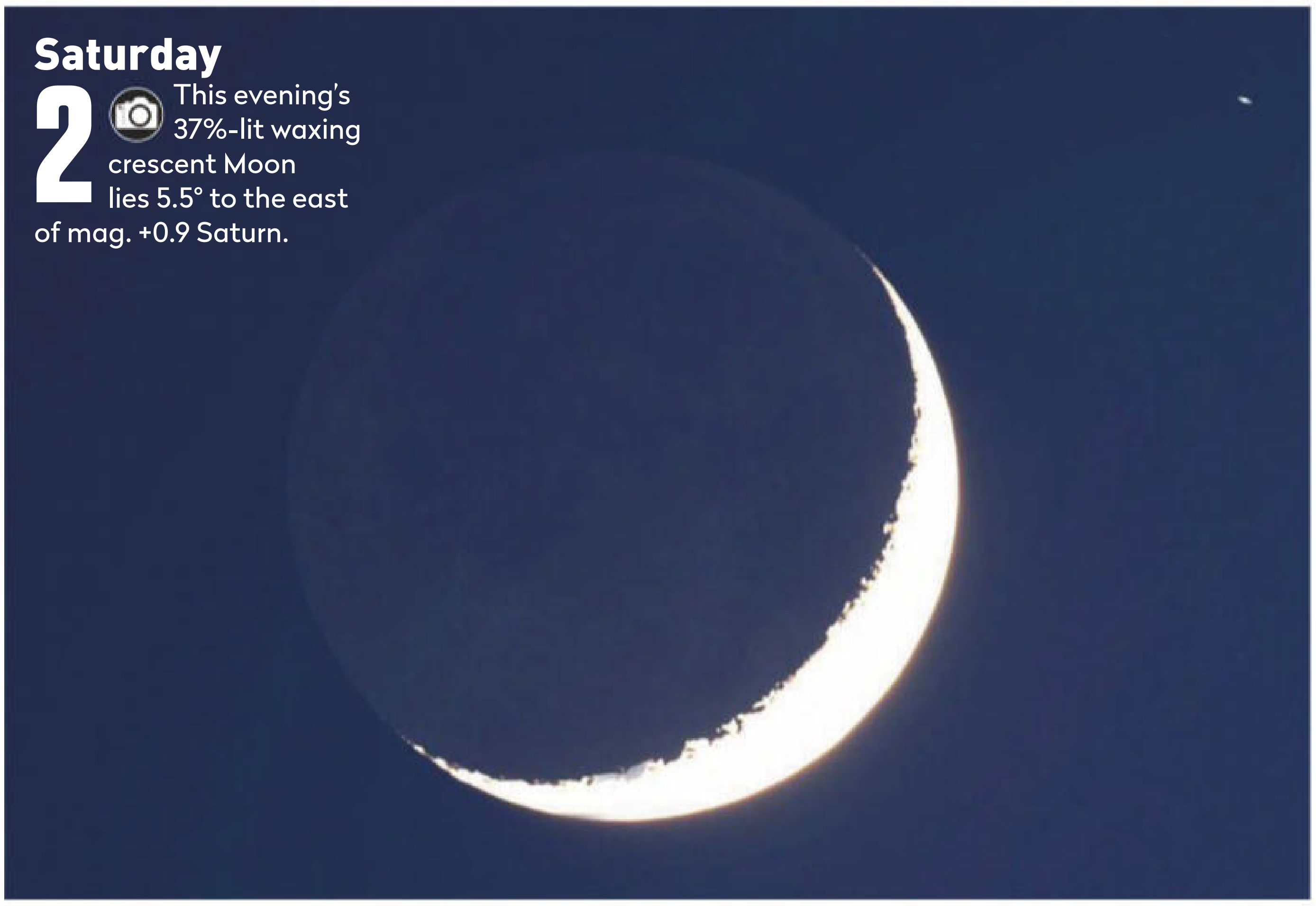
NOVEMBER HIGHLIGHTS

Your guide to the night sky this month



Saturday 2

This evening's 37%-lit waxing crescent Moon lies 5.5° to the east of mag. +0.9 Saturn.

Tuesday 5

The crater Lalande, the subject of this month's Moonwatch (see page 52), is visible this evening.

Saturday 9

Ganymede's shadow begins to transit across Jupiter's disc from 15:10 UT. This tricky observation takes place in daylight.

Tuseday 12

Early risers will see Mars 3° from mag. +1 Spica (Alpha (α) Virginis) rising above the east-southeast horizon around 05:30 UT.

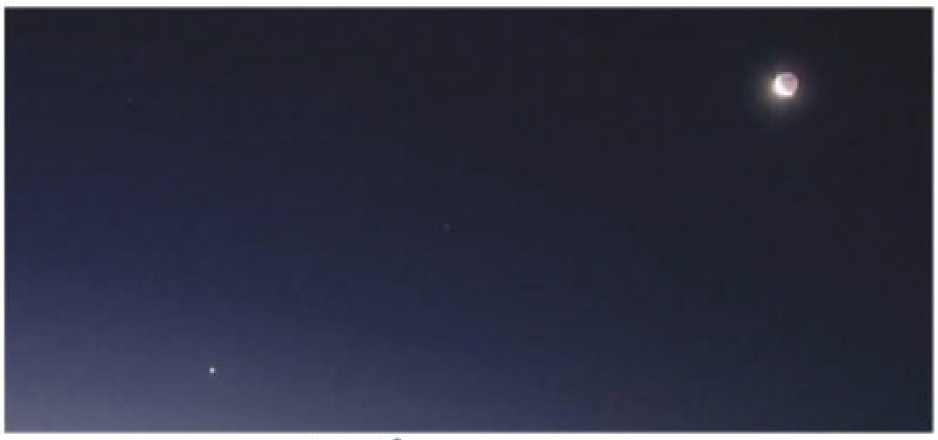
Minor planet 4 Vesta reaches opposition at mag. +6.5 in Cetus. See page 53.

Wednesday 13 ▶

Tonight and into tomorrow morning a 97%-lit waning gibbous Moon will be passing through the northern regions of the Hyades open cluster in Taurus. Mag. +0.8 Aldebaran (Alpha (α) Tauri) is 2.5° south of the Moon at 04:30 UT.

Saturday 23

This evening, tomorrow evening and the evening of the 25th, Venus and Jupiter are close, low above the southeast horizon just after sunset. Closest approach occurs on the evening of 24 November when both planets appear just 1.4° apart.



◀ Sunday 24

The early morning twilight, low above the east-southeast horizon, contains the lovely sight of mag. –0.1 Mercury, +1.7 Mars and a slender 7%-lit waning crescent Moon 4° north of Mars.

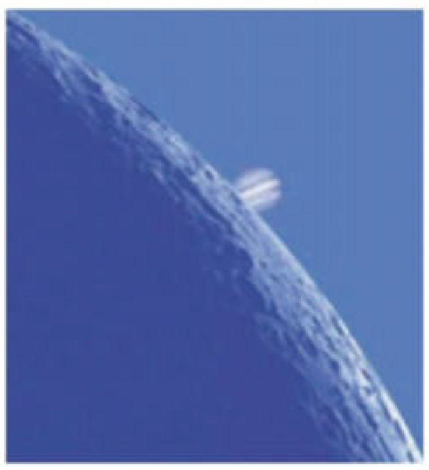
Family stargazing

Cassini's Moon Maiden is a trick of the light which makes it look as if there's a young girl sitting on the edge of the Sinus Iridum, looking out over the Bay of Rainbows. On 8 November point a telescope at the Moon. The part you're looking for is located close to the terminator in the upper portion of the Moon as seen from the UK. Try and get young eyes to spot the semi-circular bay and identify the southern cusp. This is where the Maiden sits. She's easier to see if the eyepiece you use inverts the image so north is down. www.bbc.co.uk/cbeebies/shows/stargazing

Thursday 28 ▶

Jupiter reappears from lunar occultation in daylight after 10:30 UT. See page 47.

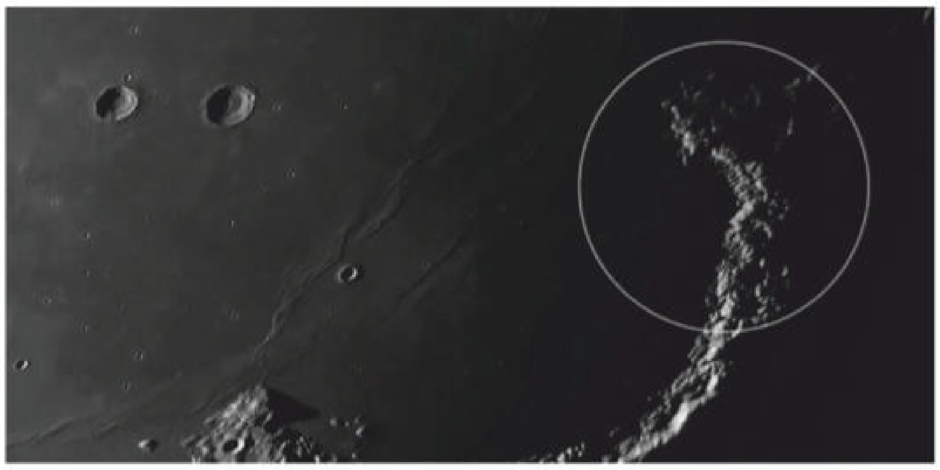
Mag. –3.8 Venus, a 4%-lit waxing crescent Moon and mag. –1.7 Jupiter appear in a line low in the southwest after sunset.



PETE LAWRENCE X 6, ALAN DYER/STOCKTREK IMAGES/ISTOCK/GETTY IMAGES

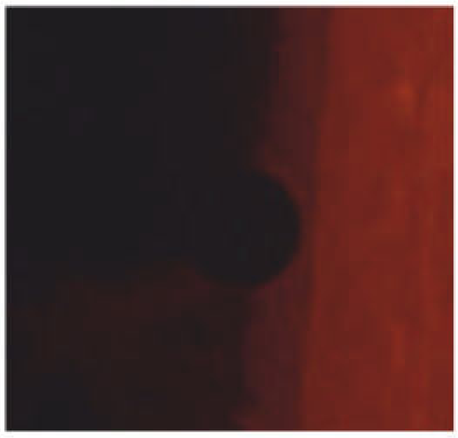
Friday ▶ 8

This evening presents an opportunity to see the clair-obscur effect known as Cassini's Moon Maiden. The Maiden is formed within the headland at the southern edge of Sinus Iridum, a feature known as Promontorium Heraclides.



Sunday 10

The Northern Taurid meteor shower reaches peak activity. Although the shower has a weak ZHR (Zenithal Hourly Rate) of just 4 meteors per hour, the peak is broad, lasting for several days.



◀ Monday 11

The planet Mercury transits across the Sun's disc from 12:35 UT this afternoon.

▸ ***Turn to pages 30, 46 and 76 for more information on how to observe and image this event.***

Sunday 17

Tonight and into tomorrow morning sees the peak of the Leonid meteor shower. The peak ZHR for the Leonids is in the region of 10–20 meteors per hour. A bright 68%-lit waning gibbous Moon will interfere this year. Turn to page 46.

Monday 18

This morning's 68%-lit waning gibbous Moon lies 3.3° to the west of the Beehive Cluster, M44.

Wednesdy 20

Look at the last quarter Moon low above the east-northeast horizon just after 00:00 UT this morning. The bright, mag. +1.3 star located 3° south of it is Regulus (Alpha (α) Leonis).

Monday 25

A slender 2%-illuminated Moon lies 2.7° east of mag. –0.2 Mercury in the morning twilight. Catch the pair low in the east-southeast from 06:30 UT.

Tuesday 26

The Moon is new today, leaving the long nights of November beautifully dark. This is an ideal time to try our Deep-Sky Tour on page 56. This month we're looking at Eridanus and Fornax, a sky location optimally placed in the run up to midnight.

Friday 29

This evening, look to the southwest after sunset where you'll find mag. +1.0 Saturn, a 10%-lit waxing crescent Moon, mag. –3.8 Venus and mag. –1.7 Jupiter close to one another, low in the southwest after sunset.

NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit **http://bit.ly/10_easylessons** for our 10-step guide to getting started and **http://bit.ly/buy_scope** for advice on choosing a scope

DON'T MISS

Transit of MERCURY

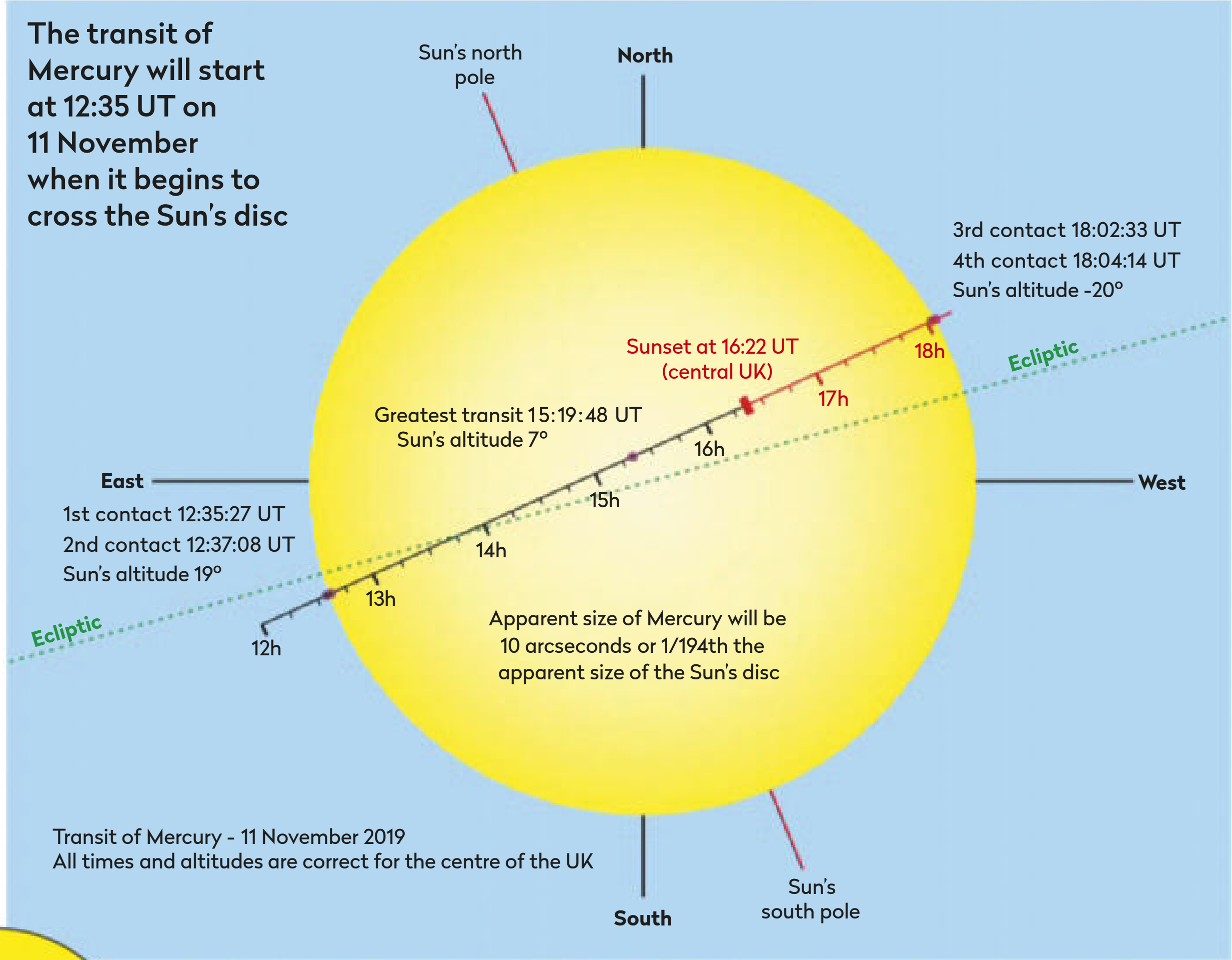
BEST TIME TO SEE: Observe on 11 November from 12:00 UT, first contact occurs at 12:35 UT

November plays host to an exciting event known as a transit of Mercury. This involves the planet appearing to cross the disc of the Sun as seen from Earth. We look at the general aspects of a Mercury transit on page 30. Here, we'll concentrate on the observational aspects.

The transit circumstances are shown on the diagram (right). This provides times for the key stages – first, second, third and fourth contacts – together with the point of greatest transit.

Observing the transit requires a scope fitted with safety filters. The scope's finder will need to be capped or removed for safety. Safety filters include those for viewing in white light, hydrogen-alpha or other narrowband wavelengths.

You'll need to work out where Mercury will first appear on the Sun's disc after first contact. The graphic (above) shows first contact occurs at the east-southeast limb. Determining where this is in your scope view is essential to see the event start.



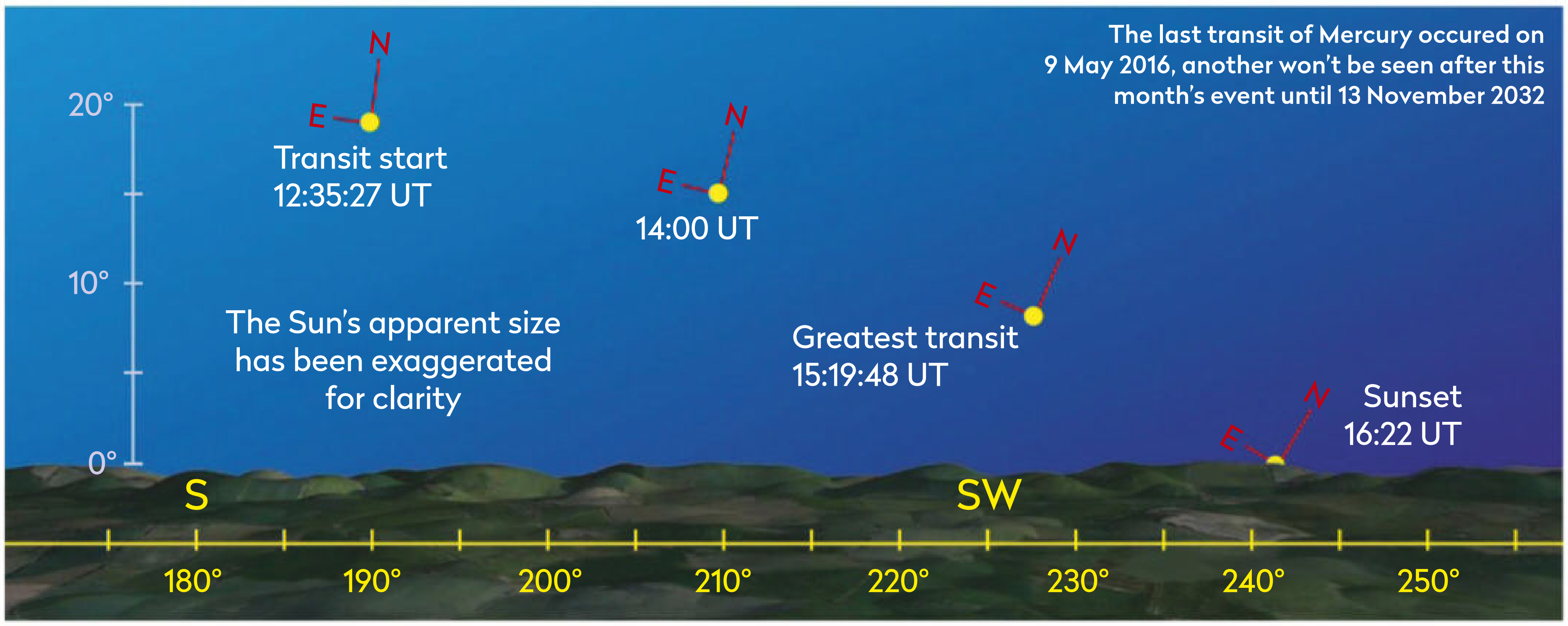
CAUTION
Never observe or image the Sun with the naked eye or any unfiltered optical instrument

Using an equatorially mounted scope set up for solar observing and with the Sun's disc centred, apply gentle pressure to the scope's top (north point) as if to push it down (south). The Sun will appear to move in the eyepiece. Its first part to touch the edge of the field of view will be its north limb. Now apply pressure to the scope tube's side as if to move it west. The first part of the Sun to touch the side of the field of view will be east. Once you've determined north and east, you can identify the east-southeast first contact limb. This technique works for an altaz mount, but only when the Sun is due south.

Mercury will appear 10 arcseconds across during the transit, 1/194th the apparent size of the Sun, and just three times larger than the apparent size of Uranus. A medium to high power eyepiece or a good camera image scale that shows just part of the Sun's disc is recommended.

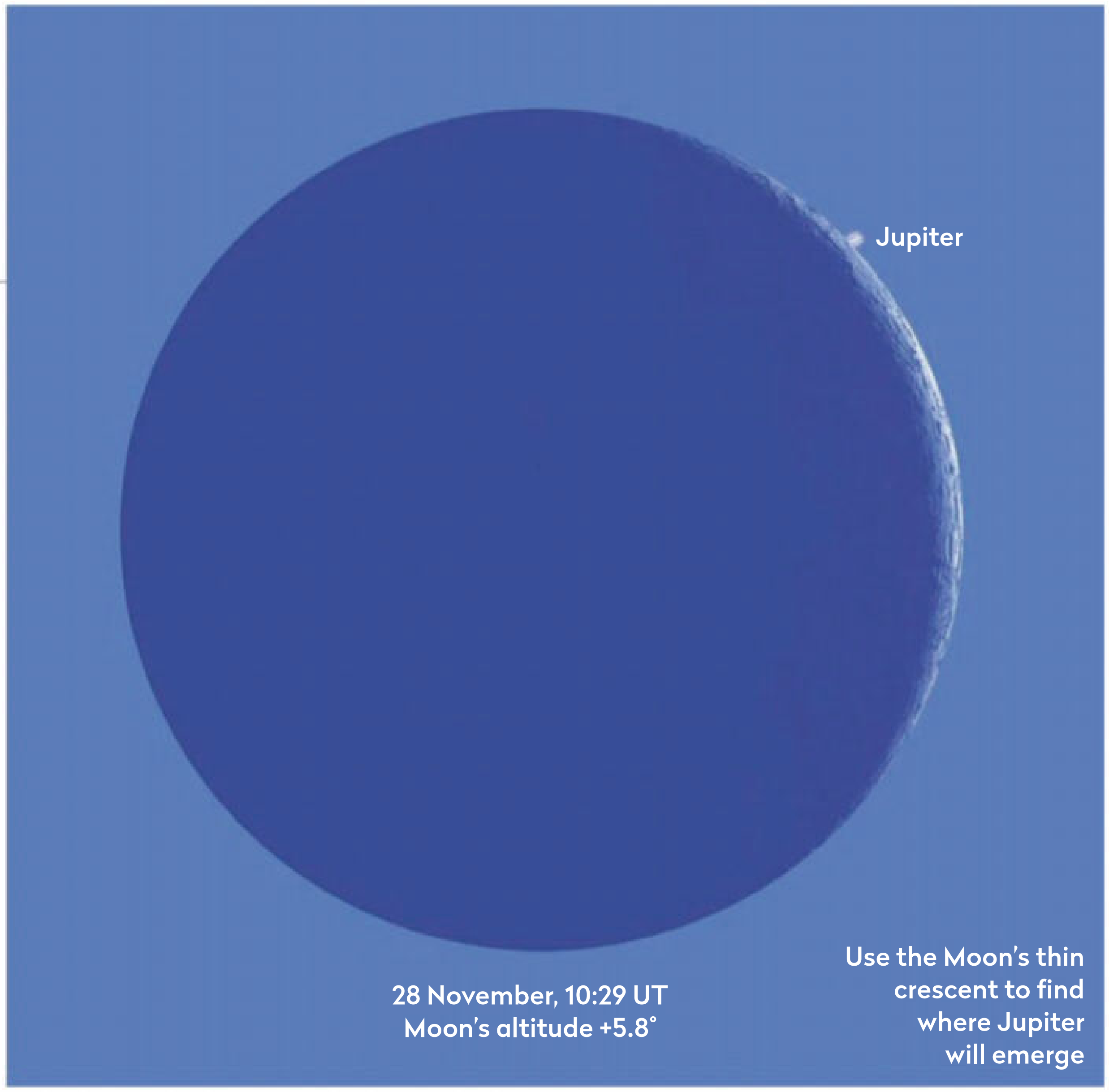
The transit begins (first contact) at 12:35 UT when the Sun's altitude is 19°. Mercury's small black dot reaches greatest transit at 15:19 UT when the Sun's altitude is around 7°. Contacts 3 and 4 sadly occur after sunset from the UK.

▸ **Find out more about the transit, and how to image it, on page 30 and 76**



ALL PICTURES: PETE LAWRENCE

Lunar occultation of JUPITER



BEST TIME TO SEE: 28 November from 10:20 UT (or as soon as possible after local moonrise)

The Moon circles around the sky once every 27.3 days – a sidereal month. As it does so it infrequently occults bright stars, blocking them from view to an observer. Despite its dominant presence in the night sky, the Moon appears small compared to the background constellations, just half a degree across.

Occultations of dimmer stars occur on a fairly frequent basis because there are many more of them to cover. However, as stars get dimmer they get harder to spot near a bright Moon.

Where occultations of bright stars are infrequent, lunar occultations of the planets are rare. When such an event occurs it's worth putting extra effort in to catch it. On 28 November, Jupiter will emerge from behind the Moon's slender waxing crescent at 10:29 UT under daylight conditions.

Jupiter can be seen through a telescope or binoculars during the day as long as you know where to look. Its disc appears ghostly, with low contrast, which makes it hard to identify. This is especially the case if the sky is hazy or altitude low. However, the presence of the Moon gives you a navigational head start. Even so, at just 4%-lit, the Moon's crescent will also be challenging to see in daylight conditions.

The altitude of the event will be very low at around 6° from the centre of the UK. It's recommended to view from a location with a flat southeast horizon. Start observing from local moonrise (no later than 10:20 UT) to give yourself plenty of time to get accustomed to the view. Timings will vary slightly with location

A high image scale or magnification will get you in closer to the event but will also reduce contrast. If the sky is hazy, consider reducing image scale or using a slightly longer focal length eyepiece to reduce overall magnification.

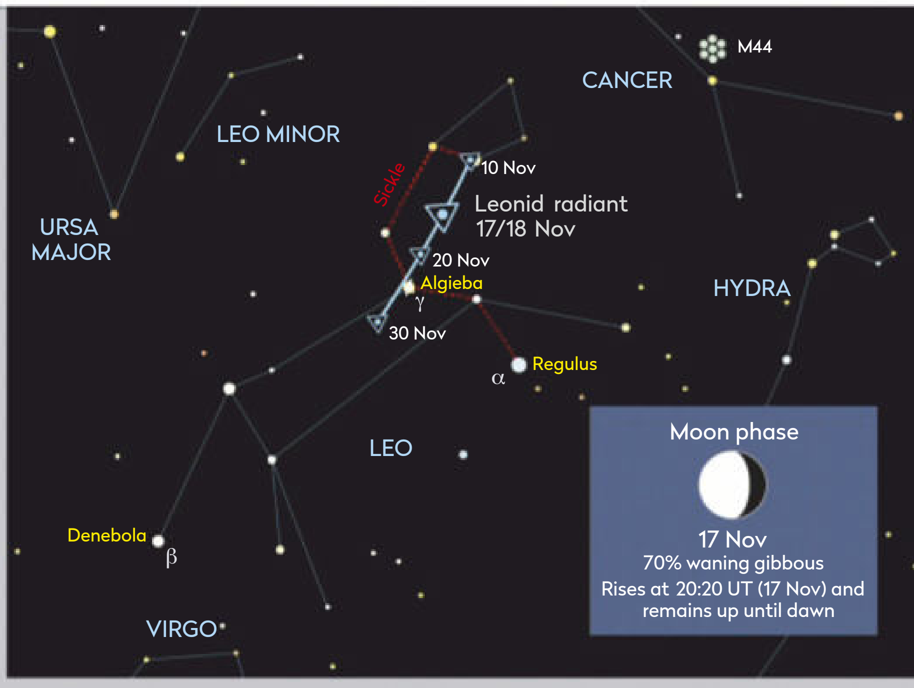
Leonids 2019

BEST TIME TO SEE: Night of 17/18 November from 22:00 UT until dawn

The Leonid meteor shower is famous for its 33-year interval storm-level activity. With impressive displays in 1933, 1966 and 1999–2002, we are currently between outbursts. Consequently, the current Leonid Zenithal Hourly Rate (ZHR) is low at around 10–20 meteors per hour.

The shower's radiant is within the Sickle asterism in Leo the Lion, the pattern which represents the front of the lion. A shower radiant is the point in the sky the shower meteors appear to emanate from due to a perspective effect. Such an easy to visualise radiant location makes it easy to determine whether a meteor trail belongs to the Leonids.

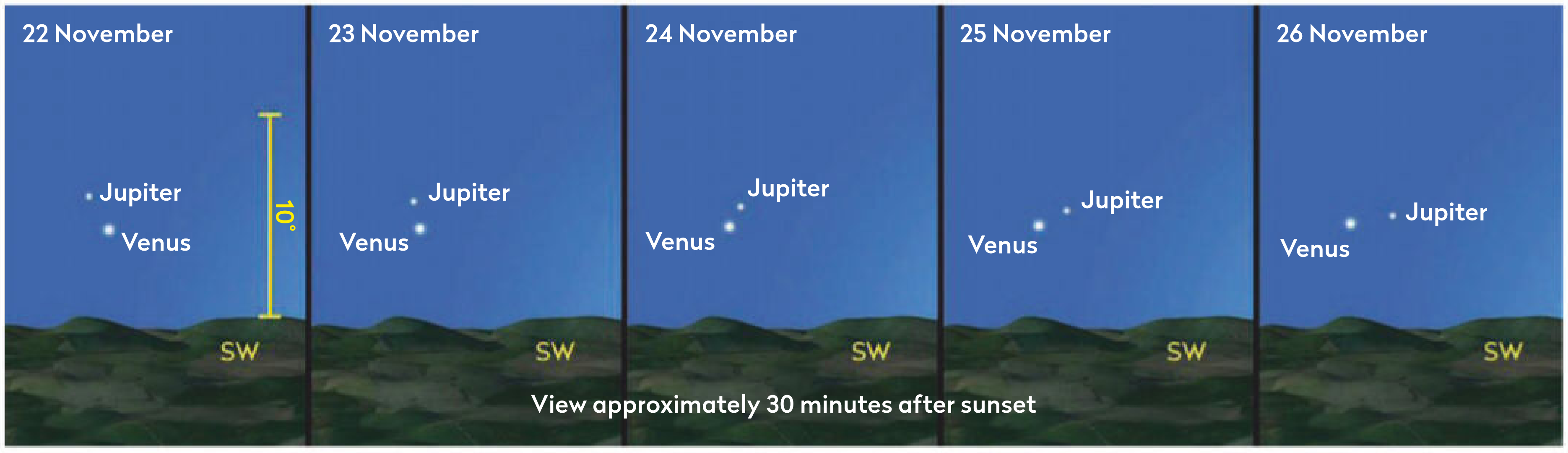
This year there will be moonlight interference. The Leonid peak occurs in the early hours of 18 November when the Moon will appear with a 70%-lit waning gibbous phase, 22° west of the radiant. Rising at 20:20 UT on 17 November and not setting before dawn, the Moon's glare will reduce the number of meteors seen.



▲ **The Leonid shower's peak (17 Nov) coincides with a bright Moon**

Observe the Leonid meteor shower by finding a dark location where the Moon is hidden from view. Look at a height around 60° (two-thirds up the sky from the horizon) in a direction where the sky is least affected by moonlight. Observe in blocks at least 30 minutes long.

THE PLANETS Our celestial neighbourhood in November



▲ **Although Venus and Jupiter often appear close together, it is unusual to see them so bright, at mag. –3.8 and mag. –1.7 respectively**

PICK OF THE MONTH

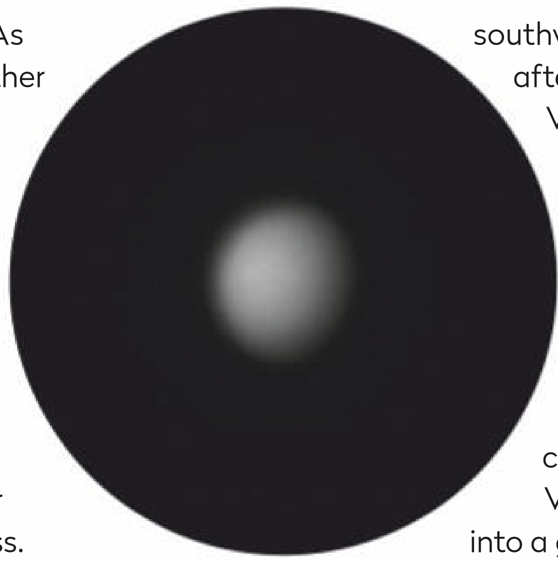
Venus

Best time to see: 24 November, 30 minutes after sunset
Altitude: 4° (low)
Location: Sagittarius
Direction: Southwest
Features: Phase, faint atmospheric markings

Venus is currently an evening object, which appears to be slowly pulling away from the Sun. On 1 November it shines at mag. –3.8 and sets approximately 50 minutes after the Sun goes down. Through a telescope the planet appears to show a 93%-lit gibbous disc which is 10 arcseconds across on 1 November. As Venus slowly moves further around its orbit on the distant side of the Sun, the angle between Earth, the Sun and Venus changes. As a result, by the end of November, Venus shows a marginally reduced phase of 89% and a fractionally larger disc, 11 arcseconds across.

The position of Venus deteriorates slightly throughout the month as it drops south below the ecliptic plane. However, its increased separation from the Sun means that it still manages to set 90 minutes after the Sun goes down on 30 November.

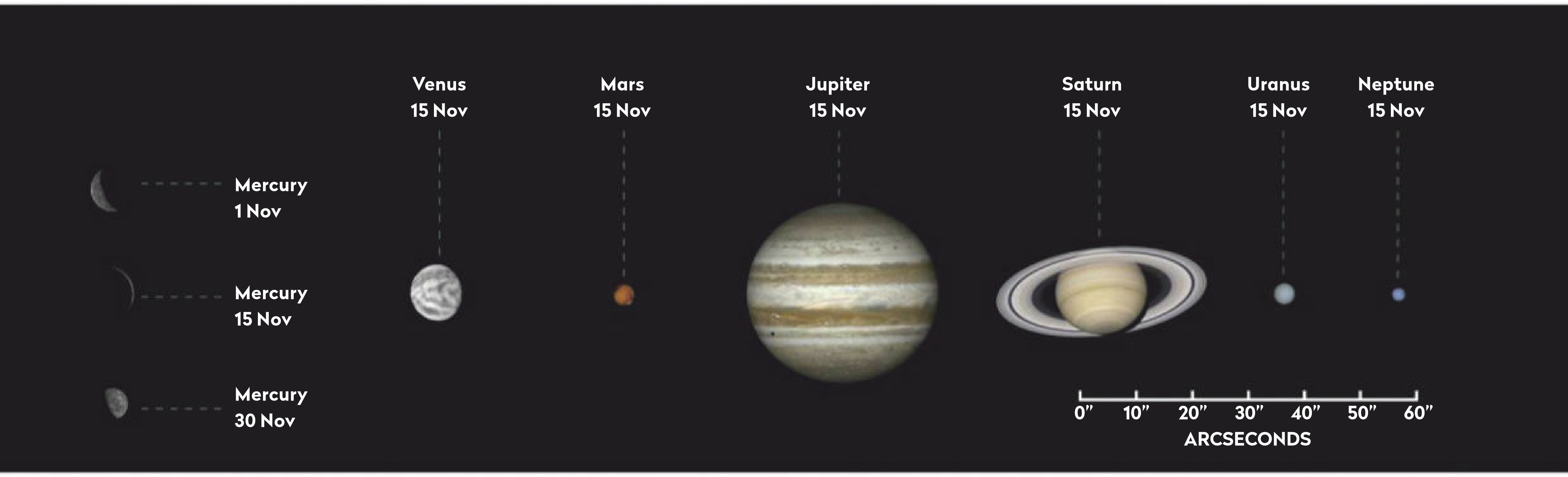
On 24 November, mag. –3.8 Venus can be seen close to Jupiter low in the southwest some 30 minutes after sunset. At this time Venus will appear 1.4° to the south of mag. –1.7 Jupiter. Although the coming together of these two planets isn't that uncommon, the fact that they are so bright can really capture the imagination. Venus is starting to move into a good position ahead of an upcoming impressive winter and spring appearance. Although there's not much to see on its disc currently, it's interesting to watch its progress through a scope as it appears to grow in size and shrink in phase. It's good to start recording this early if possible, attempting to follow it right the way through to inferior conjunction on 3 June 2020.

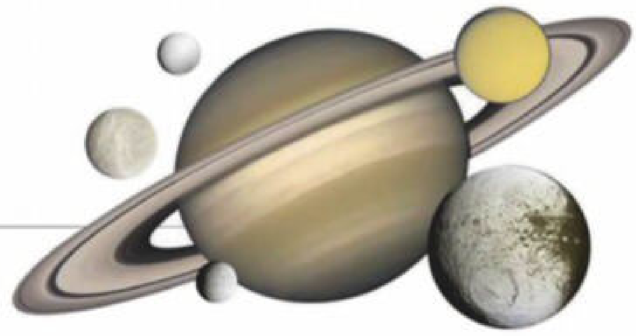


▲ **Observe the changing disc of Venus over winter and spring**

The planets in November

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope





Mercury

Best time to see: 28 November, 45 minutes before sunrise
Altitude: 9.5˚ (low)
Location: Libra
Direction: Southeast
Mercury is poorly placed at the month's start, an evening object setting just after the Sun. Inferior conjunction occurs on 11 November and then Mercury re-emerges into the morning sky. This inferior conjunction will result in a transit of Mercury (see pages 30, 46 and 76).

It's well placed on 20 November, shining at mag. +0.6 and rising 100 minutes before the Sun. The good positioning remains to the month's end. On 25 November, mag. –0.2 Mercury is less than 3˚ from a 2%-lit waning crescent Moon. Greatest western elongation occurs on 28th, with Mercury separated from the Sun by 20.1˚.

Mars

Best time to see: 30 November, 06:15 UT
Altitude: 9˚
Location: Virgo
Direction: Southeast
Mars is pulling away from the Sun in the morning sky, but remains poor telescopically due to its large distance from Earth. Mars's mag. +1.8 orange coloured dot is 3˚ from mag. +1.0 Spica (Alpha (α) Virginis) on 11 November as they rise above the east-southeast horizon.

Jupiter

Best time to see: 1 November, 17:30 UT
Altitude: 17˚ (low)
Location: Ophiuchus
Direction: Southwest
Balanced on the eastern knee of Ophiuchus, Jupiter has a low southerly declination that is making UK-based observations tricky. Its mag. –1.8 dot appears low in the southwest as night falls at the start of the month.

On 24 November, mag. –1.7 Jupiter is joined by mag. –3.8 Venus. See them after sunset above the southwest horizon. On 28th, Jupiter will reappear from a lunar occultation (see page 47) in daylight.

Saturn

Best time to see: 1 November, 18:15 UT
Altitude: 12˚
Location: Sagittarius
Direction: South-southwest
Mag. +0.9 Saturn is visible low in the south-southwest as darkness falls at the start of the month, but soon becomes too low for telescopic observation. On 1 November a 24%-lit waxing crescent Moon appears 7.5˚ west of the planet. The following evening, the now 33%-lit crescent Moon appears 5.5˚ east-southeast of Saturn. On 29 November, the 10%-lit waxing lunar crescent sits 3˚ southwest of the planet.

Uranus

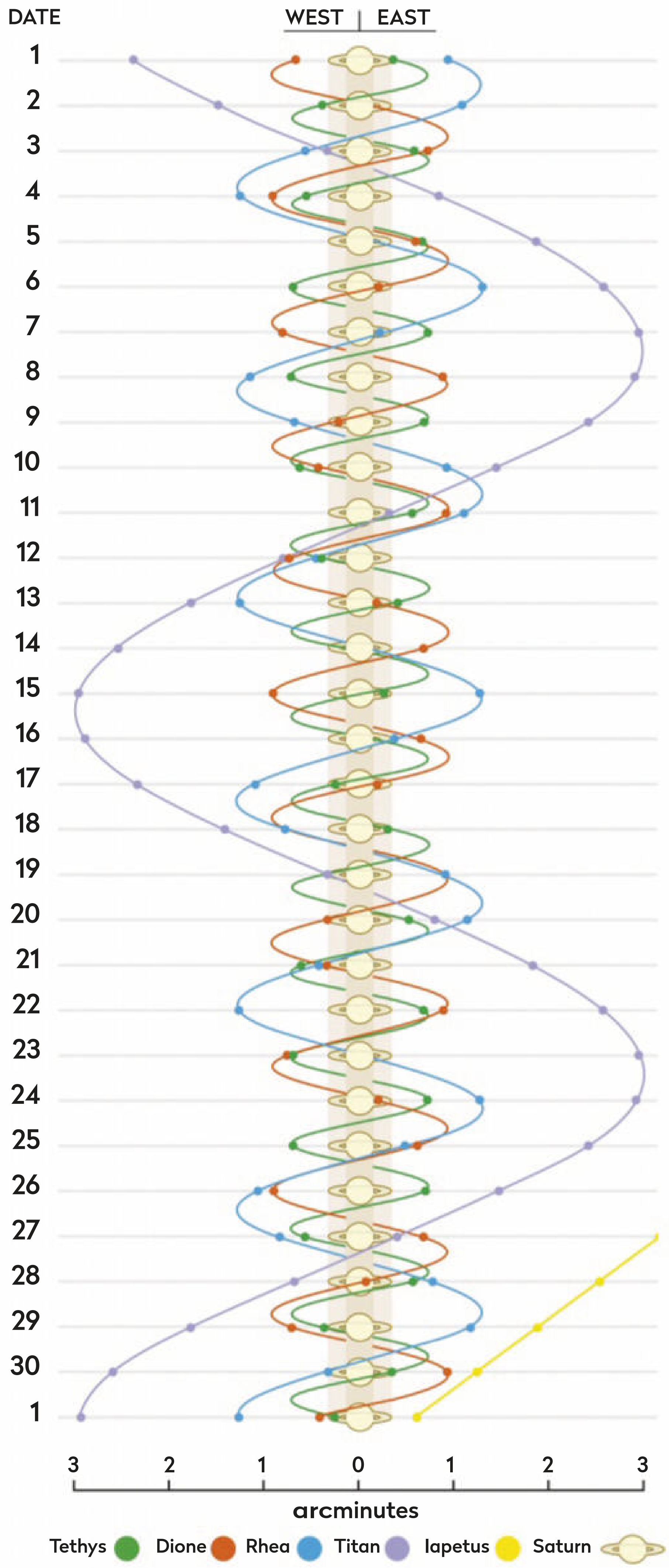
Best time to see: 30 November, 21:30 UT
Altitude: 49˚
Location: Aries
Direction: South
Uranus is well positioned in Aries. At mag. +5.7 it reaches a peak altitude of 49˚ when due south. Under a dark sky it may be possible to see the planet with the naked eye.

Neptune

Best time to see: 1 November, 20:30 UT
Altitude: 30.5˚
Location: Aquarius
Direction: South
At mag. +7.9 you'll need at least binoculars to spot Neptune among the stars of Aquarius. It's currently close to mag. +4.2 Phi (ϕ) Aquarii.

SATURN'S MOONS: NOVEMBER

Using a small scope you can spot Saturn's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date represents 00:00 UT.



THE NIGHT SKY – NOVEMBER

Explore the celestial sphere with our Northern Hemisphere all-sky chart

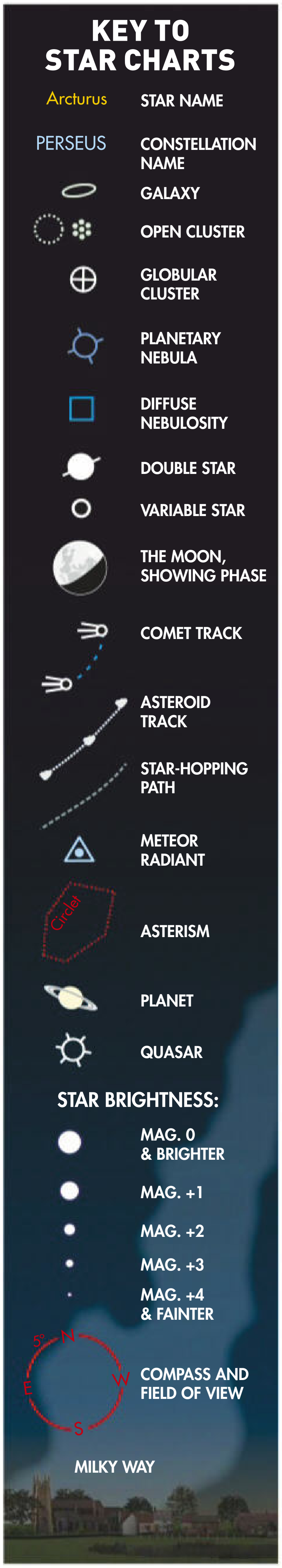


CHART: PETE LAWRENCE

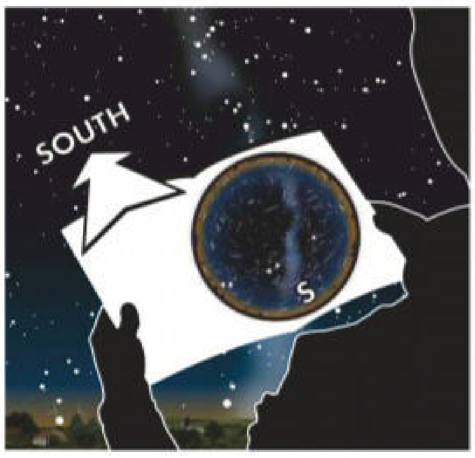
When to use this chart

1 November at 00:00 UT
15 November at 23:00 UT
30 November at 22:00 UT

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.



Sunrise/sunset in November*

Date	Sunrise	Sunset
1 Nov 2019	07:08 UT	16:38 UT
11 Nov 2019	07:27 UT	16:20 UT
21 Nov 2019	07:46 UT	16:05 UT
01 Dec 2019	08:02 UT	15:55 UT

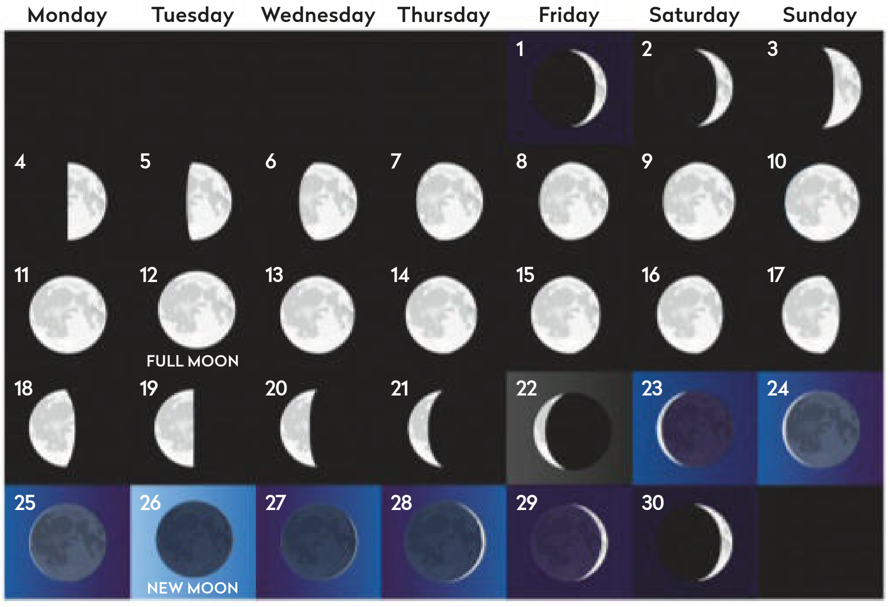
Moonrise in November*

Moonrise times

1 Nov 2019, 12:11 UT
5 Nov 2019, 14:43 UT
9 Nov 2019, 15:52 UT
13 Nov 2019, 17:08 UT
17 Nov 2019, 20:19 UT
21 Nov 2019, 00:18 UT
25 Nov 2019, 05:56 UT
29 Nov 2019, 10:54 UT

*Times correct for the centre of the UK

Lunar phases in November



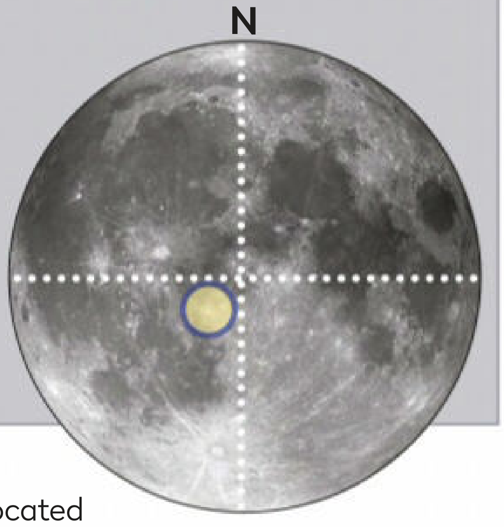
MORE ONLINE

Paul and Pete's night-sky highlights

Southern Hemisphere sky guide

Lalande

Type: Crater
Size: 25km
Longitude/latitude: 8.6˚ W, 4.5˚ S
Age: 2.2–2.8 billion years
Best time to see: One day after first quarter (5–6 November) and last quarter (19–20 November)
Minimum equipment: 50mm refractor



Lalande is a small but prominent crater located west and slightly north of the giant walled plain of 154km **Ptolemaeus**. Its two most defining features are its sharp rim and its ejecta pattern, which extends for some 300km out across the dark lava plains located west of Ptolemaeus. The brighter material that forms the ejecta pattern is easiest to see under the fuller illumination that occurs around full Moon. More obvious to the west and northwest of Lalande, it is an interesting exercise to trace the bright ejecta rays in other directions. They are evident heading towards 27km **Mosting** and appear to cover a lot of the otherwise dark lava which infills 75km **Flammarion**.

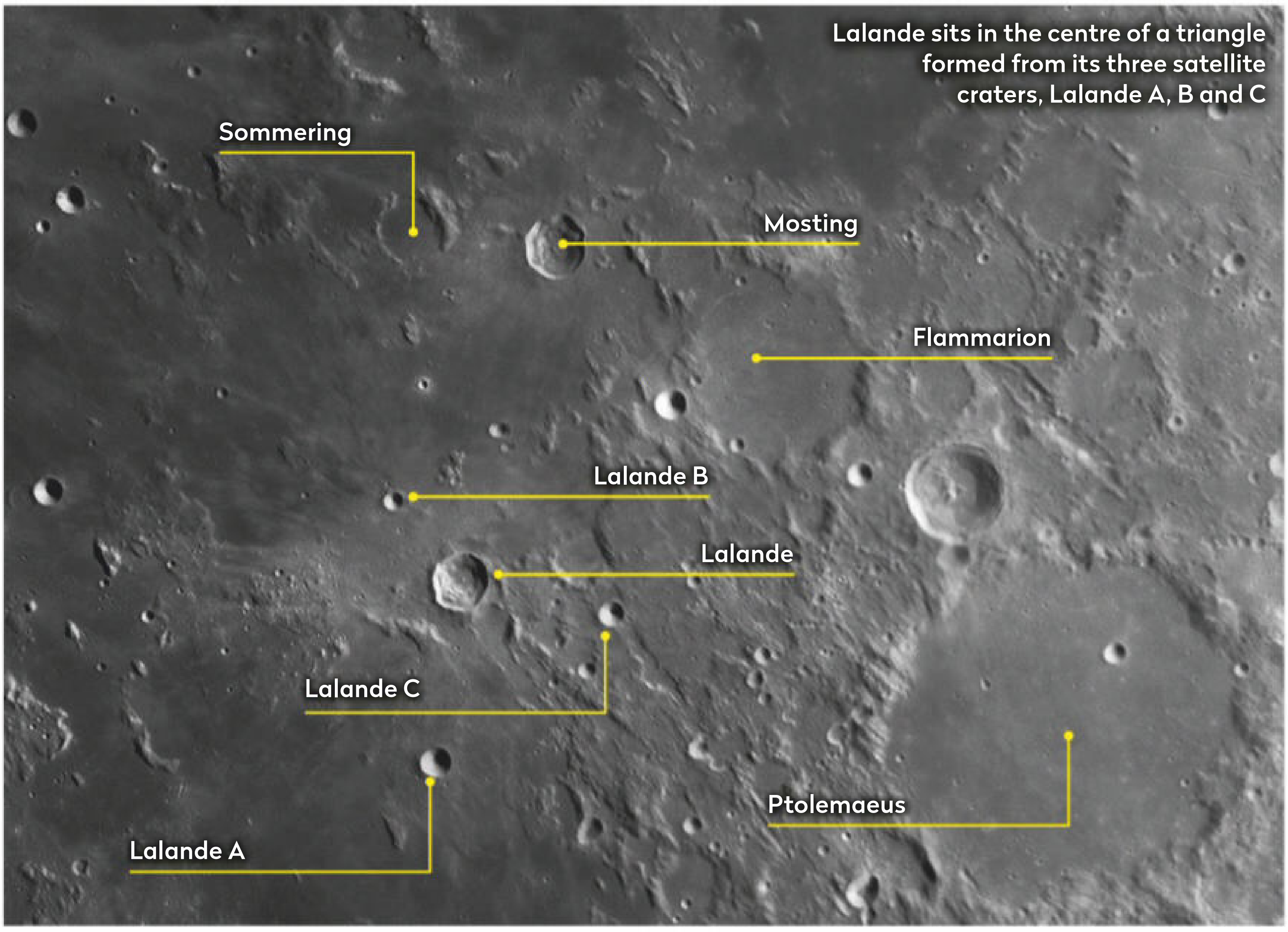
Lalande's shape is unusual too in that for the most part it looks exactly as you would expect a roughly circular crater to appear. However, the western rim section appears almost straight, perhaps even inverted slightly, bending back towards its centre. The crater's walls are terraced, a feature that stands out well at high magnification in larger scopes. There also appears to be a substantial collapse of material connected with the crater's deformed western rim. There is a small gathering of hills in the centre of Lalande's floor, but these have low elevation and are tiny. Consequently, they are best suited to larger apertures when the sun-angle is low – ie, when the terminator is nearby.

The main crater forms an aesthetically pleasing pattern with 13km **Lalande A**, 8km **Lalande B** and 11km **Lalande C**. Lalande sits in the centre of the almost equatorial triangle formed from these three satellites. Apart from their obvious size differences, Lalande A, B and C have similar appearances. Lalande B and C have steep sides with no obvious floor. Lalande A is large enough to just show a small flat floor no more than 2.5km in diameter.

The walls of Lalande A and C also exhibit banding, an effect which appears as radial light and dark streaks within a crater's wall. It's worth noting that Lalande A and C are included in the Association of Lunar and Planetary Observers (ALPO) banded craters program (**http://moon.scopesandscapes.com/alpo-bcp.htm**). Drawings, images and reports on the appearance of these features can help in categorising such craters.

Lalande's walls are terraced, a feature that stands out well at high magnification in larger scopes

Lalande also holds a surprise. In 2002, a meteorite was discovered in the desert of Oman by Edwin Gnos and colleagues from the University of Bern. Called Sayh al Uhaymir 169, it was determined that this was one of 30 Moon meteorites that had been found on Earth since 1979. The team determined that the meteorite had undergone at least four violent collisions on the Moon before being knocked into space some 340,000 years ago. It then collided with Earth. Incredibly, the team were able to determine that the rock originated from the Lalande impact crater.



Lalande sits in the centre of a triangle formed from its three satellite craters, Lalande A, B and C

PETE LAWRENCE X 5

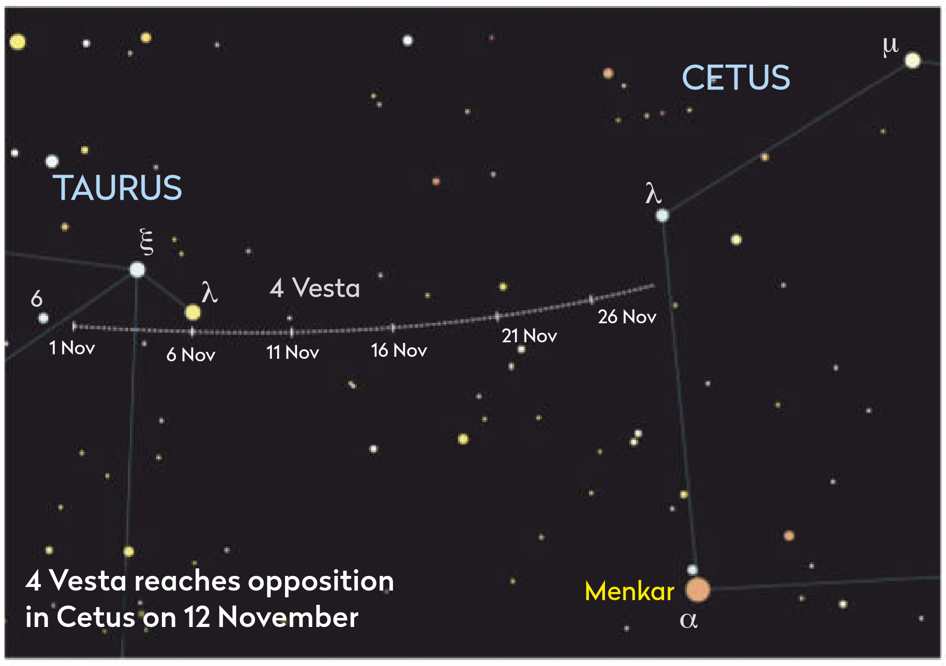
COMETS AND ASTEROIDS

Use binoculars to spot 4 Vesta, the second largest body in the asteroid belt

Asteroid 4 Vesta was discovered by Heinrich Olbers on 29 March 1807, the last of the so-called 'Big Four' asteroids discovered in the six-year period between 1801 and 1807. The previous discoveries were 1 Ceres, 2 Pallas and 3 Juno. The next discovery, 5 Astraea, didn't occur until 1845.

Vesta is the second most massive and second largest body in the asteroid belt, only being surpassed by Ceres. A lot of information is known about Vesta thanks to the highly successful Dawn mission that entered orbit around the asteroid on 16 July 2011. In addition, collisions which formed large craters on the object have resulted in debris which has fallen to Earth. Known as Howardite-Eucrite-Diogenite (HED) meteorites, these have augmented our knowledge of this fascinating world significantly.

It takes Vesta 3.63 years to orbit the Sun and at favourable oppositions it can become bright enough to be seen with the naked eye. This is the result of a high albedo of 42.3 per cent. Albedo is a measure of how much incident light is reflected back from a body. Opposition brightness can vary between mag. +5.1 and +8.5. Vesta is a large body measuring 572.6 x 557.2 x 446.4km (mean diameter 525.4km). Its orbit takes it out from the Sun as far as 2.57 AU and in as close as 2.15 AU. Despite its size, Vesta features the 505km crater Rheasilvia, one of the largest in the Solar System. The mountain peak in the centre of the crater, when measured from base to peak, is 22.5km high, making it the Solar System's tallest mountain.



4 Vesta reaches opposition in Cetus on 12 November

Vesta reaches opposition in Cetus on 12 November. It will be shining at mag. +6.5 and you'll need binoculars to see it properly. It's monthly passage against the background stars takes it from the close vicinity of mag. +3.7 Xi (ξ) and mag. +3.6 Omicron (ο) Tauri towards the head of Cetus, ending the month 4° north of Menkar.

STAR OF THE MONTH

Menkar, the flaring 'nostril' of Cetus

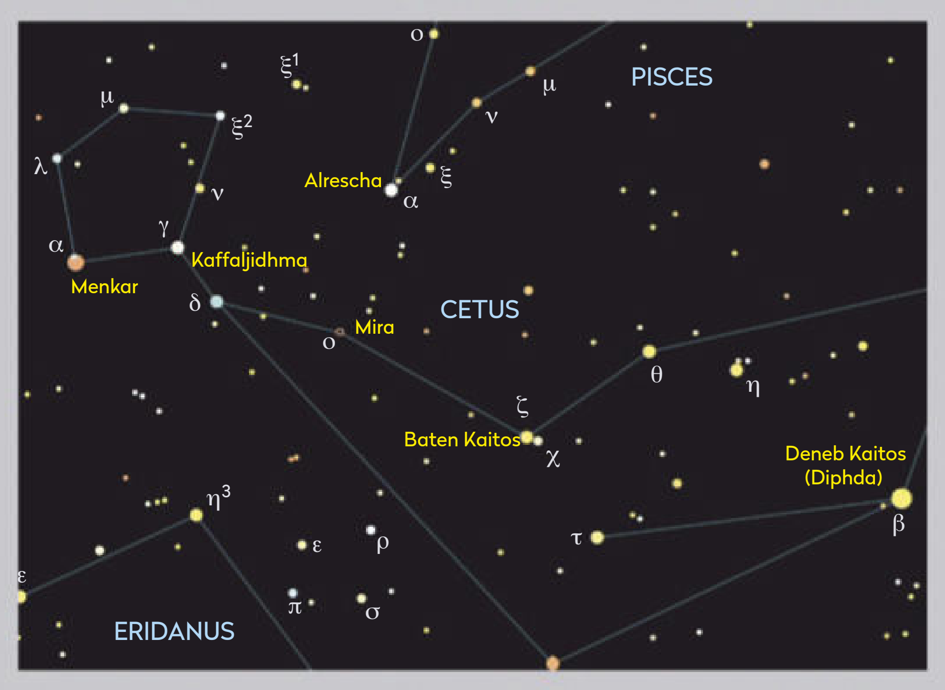
Menkar (Alpha (α) Ceti) is the second brightest star in the constellation of Cetus the Whale or Sea Monster. (The brightest is Deneb Kaitos). From the UK, Cetus is best seen in the autumn or winter months.

Menkar translates as 'nostril' and it's located in the head of Cetus. The head resembles a distorted pentagon formed from Menkar, Kaffaljidhma (Gamma (γ) Ceti), Nu (ν), Mu (μ) and Lambda (l) Ceti.

Menkar has the spectral classification M1.5 IIIa indicating that it's a cool, luminous red giant star with a 'surface' temperature of around 3,522°C. Its distance from the Sun is 250 lightyears and its luminosity is around 1,450 times that of the Sun, much of its output being in the infrared part of its spectrum. In visual wavelengths it's around 380 times more luminous than the Sun. Menkar's orange colour is easy to see with binoculars or a telescope.

Its diameter is estimated to be almost 90 times the Sun's. Menkar is also a radio source, its emissions originating from a cool stellar wind that 'blows' from its surface. The star is also variable, exhibiting a variation in brightness in the order of one hundredth of a magnitude.

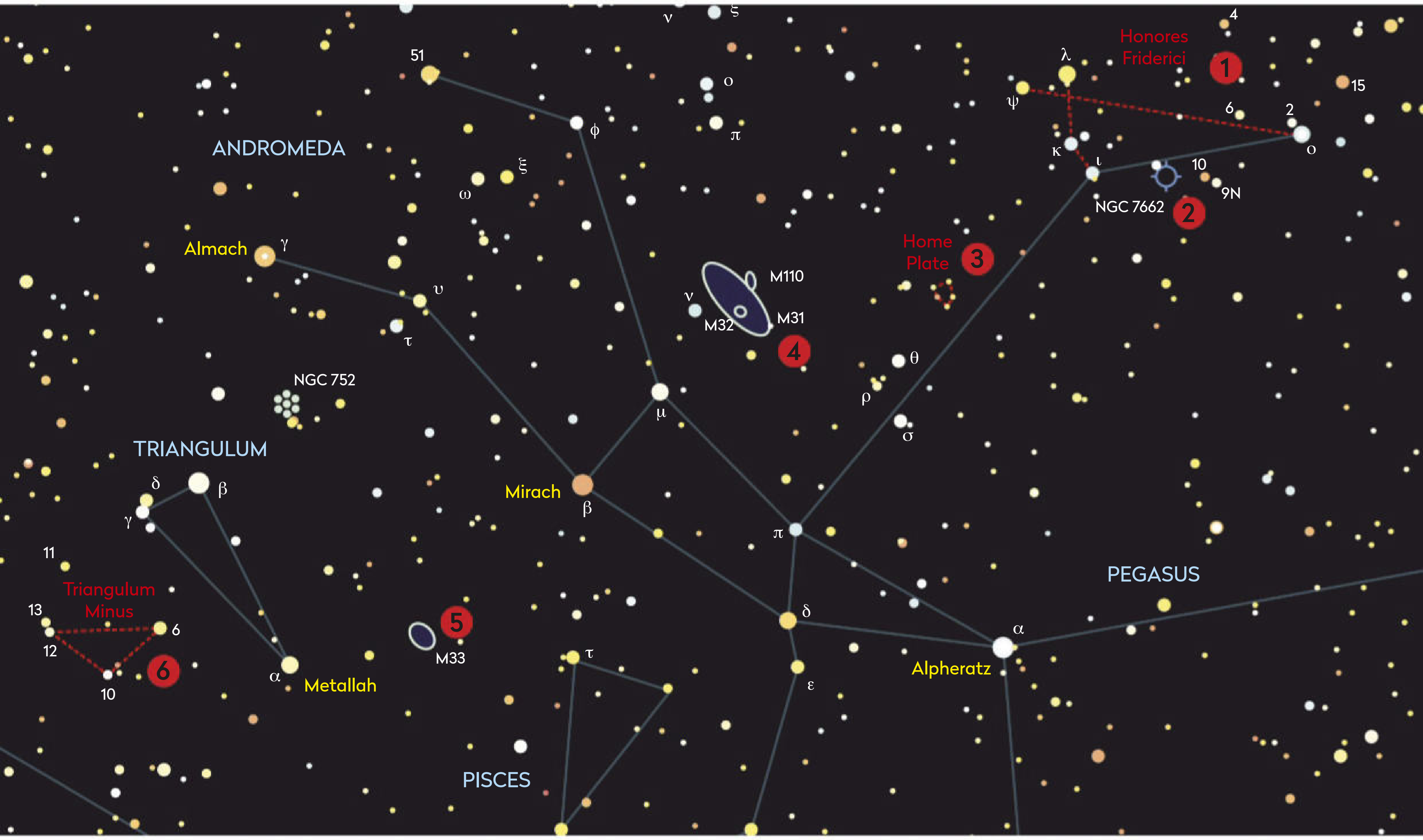
It's a star in the latter stages of evolution, having exhausted its core hydrogen and helium. The remaining carbon core is contracting and this will lead to Menkar becoming unstable like Mira. Eventually, Menkar will shed its outer layers into space and these will form a planetary nebula. After this the core of the star will remain as a white dwarf.



▲ Although Menkar is Cetus's alpha star, Deneb Kaitos is brighter

BINOCULAR TOUR With Steve Tonkin

We pitch in with some baseball knowledge, and take in some obsolete constellations



PETE LAWRENCE X 5

1. Honores Friderici

10x50 Before the IAU formalised the 88 modern constellations, several astronomers invented their own. Johann Bode created Honores Friderici (Frederick's Glory) in 1787 to honour Frederick the Great of Prussia. It takes the form of a ceremonial sword and writing quill, wreathed in laurel. Binoculars allow you to appreciate the varied colours of the stars in this region, ranging from ruddy 8 Andromedae to blue-white Omicron (ο) Andromedae. ☐ **SEEN IT**

2. NGC 7662

15x70 Identify Iota (ι) Andromedae, part of the hilt of Frederick's sword, and scan 2° west to 13 Andromedae. You'll find NGC 7662 half a degree to the south-southwest. It looks like an 8th magnitude star, but 70mm binoculars should help to bring out the blue-green tint that distinguishes it from the surrounding, mostly white, stars. ☐ **SEEN IT**

3. The Home Plate

10x50 Here's one for any baseball experts: start at Theta (θ) Andromedae and pan 2½° (about half a 10x50 field of view) northwest where you will find an irregular pentagon of yellowish 7th magnitude stars. It covers an area about ½° x ¾° and looks just like the mat that a baseball batter must touch to score a run. Three of the corners are multiple stars: can you see which ones? ☐ **SEEN IT**

4. M31

10x50 Start with the yellow star Mirach (Beta (β) Andromedae) at the south-east of the field of view and find Mu (μ) Andromedae towards the other edge. Place μ where Mirach was and the elliptical shape of M31 will be where μ was. Under urban skies, you may only see the core, but from a dark site you should notice that the glow of the galaxy extends about half-way across the field of view of 10x50 binoculars. ☐ **SEEN IT**

5. M33

10x50 You'll need a dark transparent sky for our next object. Return to Mirach and imagine a point that is diametrically opposite it from M31. Here you will find the ghostly glow of M33, perhaps appearing only as a slight brightening of the sky with averted vision. It is face on to us and appears about the same size as the Moon. ☐ **SEEN IT**

6. Triangulum Minus

10x50 We'll finish with another defunct constellation. Back in the 17th century, Johannes Hevelius split up the tiny Triangulum constellation into two tinier ones, Triangulum Majus and Minus. The little triangle is formed by three 5th magnitude stars that Hevelius was the first to catalogue: 6, 10 and 12 Trianguli. The two triangles were reunited, but the little triangle is still a nice binocular object. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

THE SKY GUIDE CHALLENGE

CAUTION
Never observe or image the Sun with the naked eye or any unfiltered optical instrument

See if you can catch one of the season's spectacular colourful sunsets


Portsmouth's Spinnaker Tower, silhouetted by the setting Sun – taken from 22km away

Few can resist the natural beauty of a sunset and the beautiful colours appearing at this time of year are truly sublime; deep blue vignetting into yellow, orange and red. Viewing the setting Sun without filters is not recommended as harmful radiation can still cause eye damage. A camera however, can fare better.

This month's challenge is simply to produce a spectacular image of the Sun's last moments before it slips beneath the horizon. And of course, there's a special sunset on 11 November as Mercury will still be in transit at sunset (see page 46)

As ever it pays to show caution. When the Sun is less than a degree above the horizon, the thicker layer of atmosphere its light has to pass through attenuates its output. It also scatters more of the blue end of the spectrum leaving the predominantly orange-red tones to dominate.

A safe way to achieve a camera view of sunset is to apply solar safety film to a telescope. Remember to cap any finder scopes before pointing at the Sun, though, as failure to do this may result in their cross hairs burning out. Once the filter has been fitted, point the telescope at the Sun and use your camera's Live View mode to get a precise alignment. Rotate the camera so the horizon is parallel with the edge of the camera frame.

Focus the image as best you can, zooming into the edge of the Sun's disc. This can be tricky to get right as the solar limb often appears to boil when the Sun's altitude is low. At your own risk, when the Sun has an altitude less than an apparent solar radius it's possible to remove the solar safety filter and image directly. Discretion needs to be applied here and if you're not sure what you're doing, don't try. If you do decide to remove the filter, do not look through the camera's viewfinder and never leave the setup unnecessarily looking at the Sun if you're not taking photos. In such circumstances, simply reapply the safety filter until you're ready.

Use your camera's lowest ISO value and set the exposure to the fastest shutter speed. Take a shot and examine for over-exposure. If the Sun's disc is over-exposed, re-fit the filter. If the Sun is dim enough not to over-expose, adjust the exposure so the Sun appears bright but its disc shows colour and doesn't appear white.

Sunsets are a spectacle in their own right, but with a bit of planning or simply by monitoring how the Sun moves from one evening to the next, it's possible to enhance an image with a foreground silhouette. If you are up to the challenge, it's possible to achieve something truly spectacular.



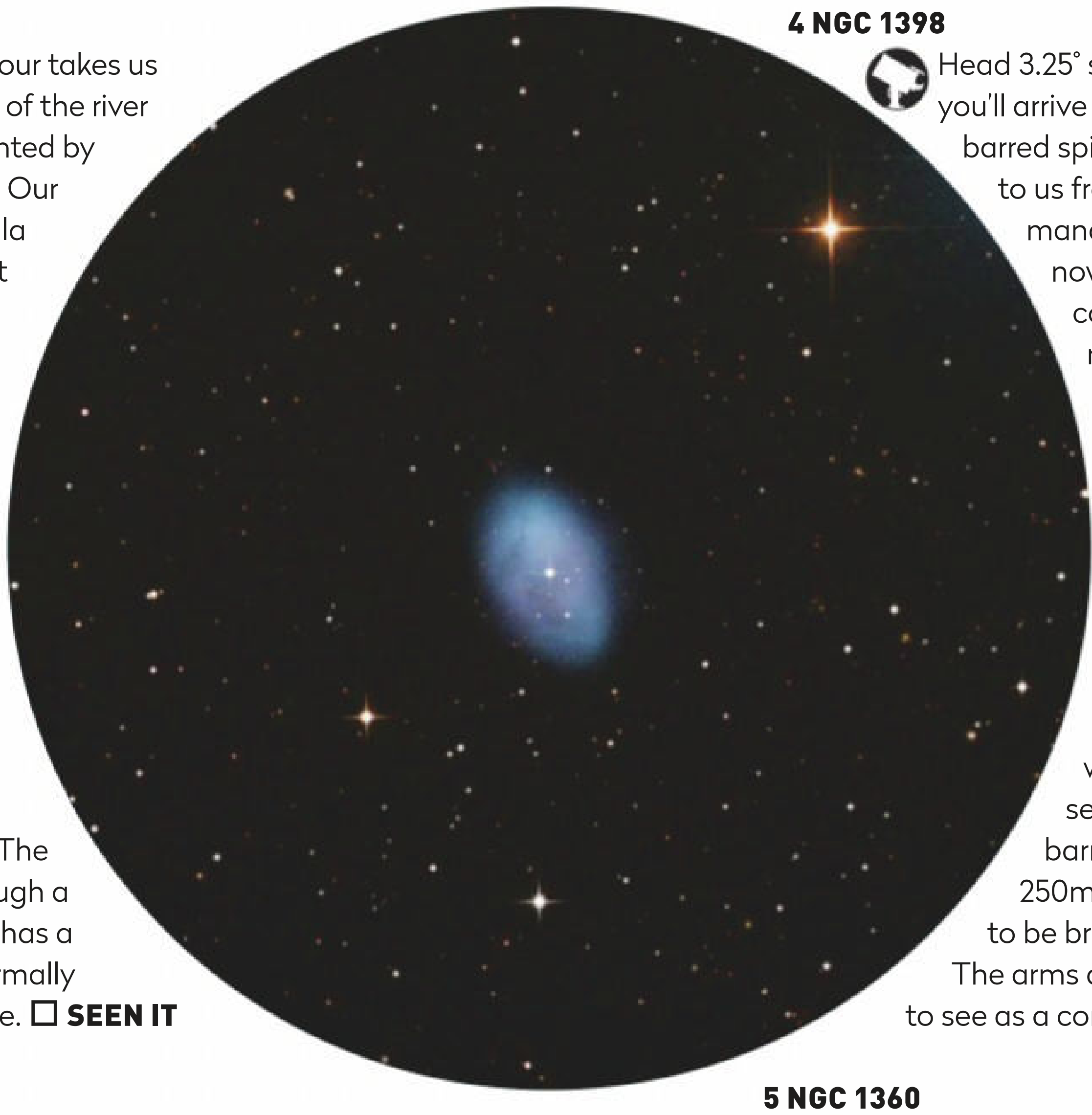
▲ **Seeing red: why not use foreground buildings, pylons or clouds to frame your dramatic sunset photographs**

DEEP-SKY TOUR

Our wide-field treasures include ghostly nebula, NGC 1535, and barred spiral galaxy, NGC 1398

1 NGC 1535

Our Deep-Sky Tour takes us along the banks of the river Po, mythologically represented by the constellation Eridanus. Our first stop is planetary nebula NGC 1535 which lies 4° east and 1° north of mag. +3.0 Zaurak (Gamma (γ) Eridani). This is a lovely object that shines at mag. +9.6. A 150mm (6-inch) scope will show it as a bright inner disc surrounded by a broken dimmer outer ring. A 250mm (9-inch) scope shows a structure over half an arcminute across with the central disc measuring 20 arcseconds. The central star is evident through a 250mm scope. The object has a blue-green hue and is informally titled the Ghost of Neptune. ☐ **SEEN IT**



4 NGC 1398

Head 3.25° south of NGC 1395 and you'll arrive at NGC 1398, an isolated barred spiral which appears face on to us from Earth. If you've managed to locate it you have now technically left the confines of Eridanus and moved into Fornax the Furnace. NGC 1398 shines at mag. +10.6 and lies 65 million lightyears from the Sun. There have been some gorgeous images of this galaxy which show a bright nucleus with a delicate ring formed from tightly wound spiral arms, separated from the main barred core. Visually, a 250mm scope shows the core to be bright, small and round. The arms are there but are hard to see as a complete ring. ☐ **SEEN IT**

2 NGC 1407

Next is galaxy NGC 1407. Head back from NGC 1535 to its navigational anchor Zaurak, and from this star head 6.5° southwest. We're now in a region of sky quite low from the UK; a dark and clear night is recommended. As galaxies go, NGC 1407 is bright at mag. +9.8. A 150mm scope shows it as a 1 arcminute glow with a bright star-like core. A 250mm scope reveals a larger halo around 90 arcseconds across. NGC 1407 is an elliptical galaxy lying at a distance of 76 million lightyears. ☐ **SEEN IT**

3 NGC 1395

South of NGC 1407 is part of a sequence of stars represented by the Greek letter Tau (τ). The sequence runs from Tau-1 (τ^1) to Tau-9. Heading south-southwest from NGC 1407 brings you to mag. +4.3 Tau-5 Eridani. NGC 1395 sits 1.8° southeast of this star. This is another elliptical galaxy, dimmer than NGC 1407 at around mag. +11. At low powers it looks like a star and is easy to miss. A 250mm scope shows a bright, circular core with a halo that extends out to 75x45 arcseconds. NGC 1395 lies 74.4 million lightyears from our Sun. ☐ **SEEN IT**

KONSTANTIN VON POSCHINGER/CCDGUIDE.COM, CHART BY PETE LAWRENCE

▲ The Robin's Egg Nebula, NGC 1360 can be located with low-power instruments

5 NGC 1360

We remain in Fornax for our penultimate target, the Robin's Egg Nebula, NGC 1360. This is a large and bright planetary nebula located 1.3° west-northwest of NGC 1398. It shines with an integrated magnitude of +9. Its central star – the one from which the nebula formed – is mag. +11.4 and is an easy target even through smaller instruments. Use a low power to make it stand out. A 150mm scope shows a 6x3 arcminute smooth glow, a 300mm (11-inch) scope extending the glow to 7x4 arcminutes and revealing a variation in brightness across the nebula. The region just north of the central star appears brightest, that immediately south darkest. It lies at least 1,145 lightyears from the Sun. ☐ **SEEN IT**

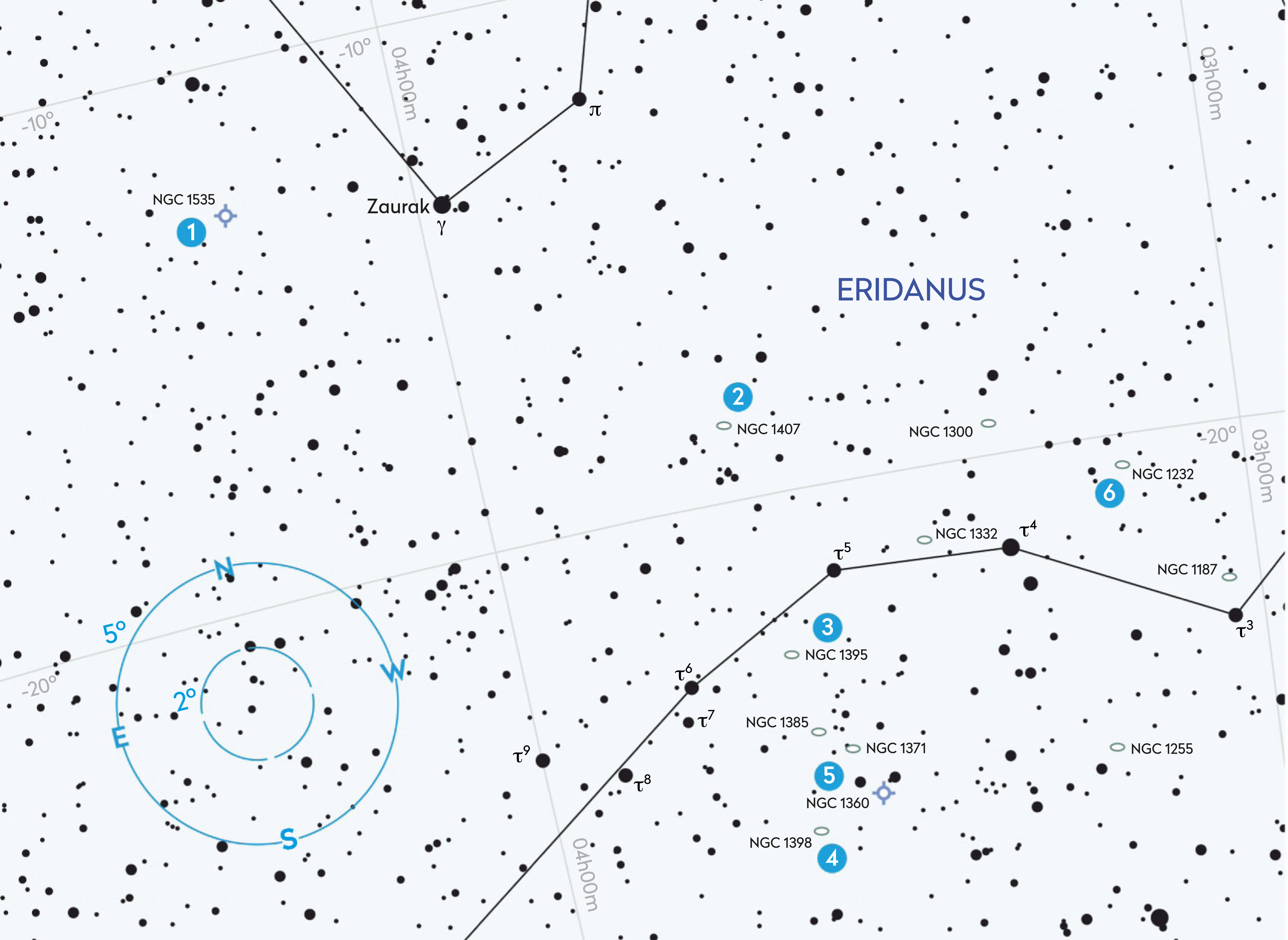
6 NGC 1232

Our final target returns us to the banks of the Po. From NGC 1232 head 4.3° north to Tau-5 Eridani. Head 3.3° west to mag. +3.7, Tau-4 Eridani. Intermediate spiral galaxy NGC 1232 lies 2.5° northwest of this star. NGC 1232 appears face on, but, unlike NGC 1398, it has a more uniform appearance; a core dimming slowly as you move out. A 150mm scope shows a bright, round, fuzzy glow about 3 arcminutes across. A 250mm scope increases its apparent size and reveals a more definite core half-an-arcminute across. A 300mm scope increases the apparent size to around 5 arcminutes and shows the core to be unevenly illuminated. NGC 1232 is estimated to be 61 million lightyears from the Sun. ☐ **SEEN IT**

This Deep-Sky Tour has been automated
ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

More **ONLINE**

Print out this chart and take an automated Go-To tour. **See page 5 for instructions.**


ERIDANUS
Zaurak
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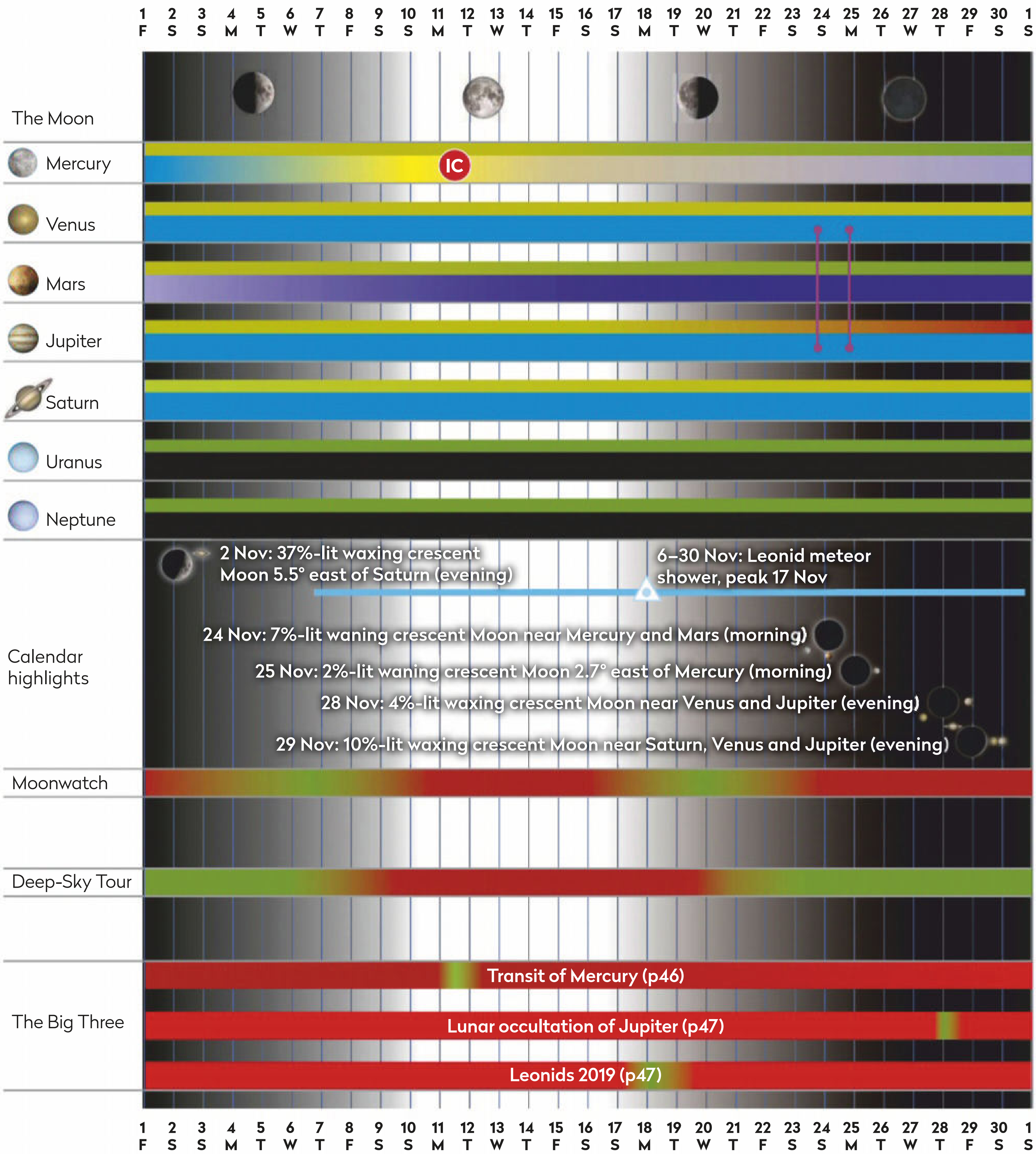
AT A GLANCE

How the Sky Guide events will appear in November



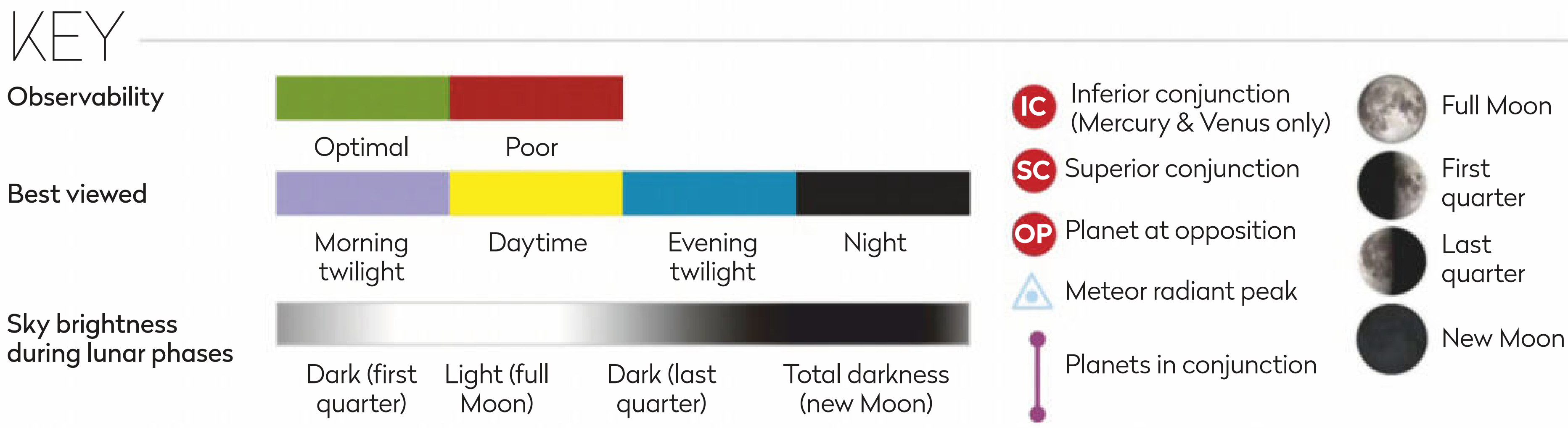


CHART BY PETE LAWRENCE

BIRTH OF TRULY BEAUTIFUL ASTROPHOTOGRAPHY

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Pro APO 80/500 Triplet OTA		
Weight 3.7 kg | 8.2 lbs	60856	989
Pro APO 80/500 Triplet Carbon OTA		
Weight 3.4 kg | 7.5 lbs	60857	1019
Pro APO 90/600 Triplet OTA		
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Astronomers, YOUR PLANET NEEDS YOU!

Amateur and professional astronomers have a unique viewpoint to share on climate change and the environment, says **Darryl Quantz**

Down to Earth: astronomers can use their skills to help protect our planet

MIKEMAREEN/ISTOCK/GETTY IMAGES

▲ **Rebel with a cause: Greta Thunberg has sparked a worldwide protest on climate issues**

The previous year has seen a dramatic increase in worldwide attention and concern about climate change and wider environmental degradation. David Attenborough's documentary *Blue Planet II* provided a new insight into the problems of plastic in our oceans, while Greta Thunberg has provided a thoughtful voice for her generation, galvanising action around the world. Unprecedented fires from the Arctic to the Amazon have attracted international attention, with multiple national and local governments declaring climate emergencies. These factors will only increase the pressure on world leaders as they meet for COP25, the United Nations Climate Change Conference, in Santiago, Chile this December.

While heads of government discuss progress towards global climate goals, every citizen also has a role to play. And astronomers – amateur and professional alike – have a special place in the environmental movement. From roots in empirical evidence to the unique observations of Earth from space, the voice of astronomers can be one of the strongest in protecting our home planet.

To look at some of the reasons why, let's start with the discovery of exoplanets in our Galaxy. As the number of alien worlds we know of has multiplied over the past 30 years, it has also reinforced the value of our home in the Universe. Most exoplanets we've found are not likely to be hospitable to life as we know it and while visions of colonising the stars are popular in science fiction, the reality is different. The closest potentially habitable planet, which may be orbiting our nearest star, Proxima Centauri B, is 4.37 lightyears away. The journey would take tens of thousands of years.

Closer to home is Mars, and the idea of colonising the Red Planet has increased in recent years, but astronomers recognise the difficult challenges of radiation and lack of resources that will need to be overcome to land people on Mars. In contrast, inter-governmental reports have given us a 12-year timeline to make progress on climate goals to avoid the worst impacts of global warming. Astronomers more than anyone should recognise the value of our home planet, perhaps best summed up by former UN head Ban Ki-moon, who responded to the climate change debate by noting "There is no Plan B, because there is no Planet B".

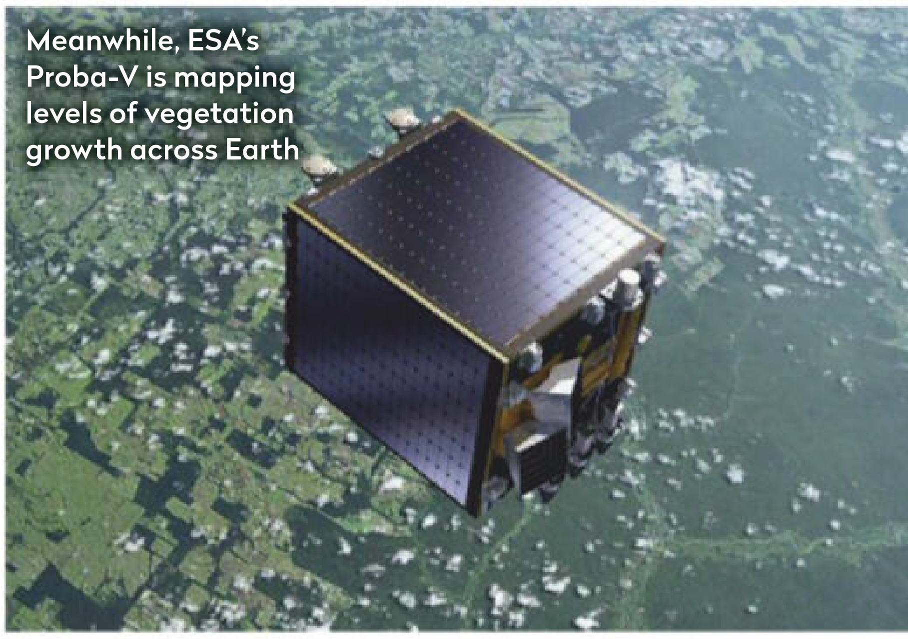
Astronomers ask many questions about our Universe, but one of the most compelling is, are we

Red Planet redemption: colonising Mars may seem an attractive prospect, but is Earth's global warming a more urgent issue?

"There is no plan B, because there is no planet B. If we do not take action now we will have to pay much more" – former UN head Ban Ki-moon

INSIDEFOTO SRL/ALAMY STOCK PHOTO, E71LENA/ISTOCK/GETTY IMAGES, SUEDDEUTSCHE ZEITUNG PHOTO/ALAMY STOCK PHOTO, ESA/P. CARRIL X 2, NASA

► On a mission: ESA's CryoSat is monitoring how the volume of ice on Earth is changing



Meanwhile, ESA's Proba-V is mapping levels of vegetation growth across Earth

alone? Underlying many missions has been the desire to understand if there is life out there, from the Viking Mars Lander's experiments in the 1970s to the first Venus missions. Many missions later, and our increased understanding of Mars and Venus underscores Earth's unique circumstances: the existence of stable conditions on a planet for the billions of years needed to allow life to not only develop, but evolve.

Signs of life

We will continue to search for life through missions to the icy moons of Jupiter and Saturn but right now, we know that there is only one planet teeming with life: Earth. Looking further afield outside our Solar System, exoplanet analysis and the SETI (Search for Extraterrestrial Intelligence) programme have yet to reveal signs of life; some argue that we may be alone in the Galaxy, indeed the Universe. This knowledge would be profound in its impact on our appreciation, and willingness to protect, the amazing diversity of life that stable planetary conditions have allowed on our planet.

Space agencies such as NASA, ESA, JAXA and Roscosmos have played a vital role in helping to understand climate change and its impact on Earth. Satellites provide vital environmental information such as average temperatures, levels of CO_2 and the thickness of polar ice caps. This is critical to understand the impact of humanity on our planet.

However, it is perhaps space travel – manned and robotic – that plays the most important role in changing hearts and minds around the environment. Voyager's Family Portrait showed Earth as a pale blue dot, and the descriptions of Earth's fragility and beauty told by generations of astronauts have arguably helped to spark the environmental movement. As Shuttle and International Space Station astronaut Ron Garan said, "When we look down at Earth from space, we see this amazing, indescribably beautiful planet. It looks like a living, breathing organism. But it also looks extremely ►

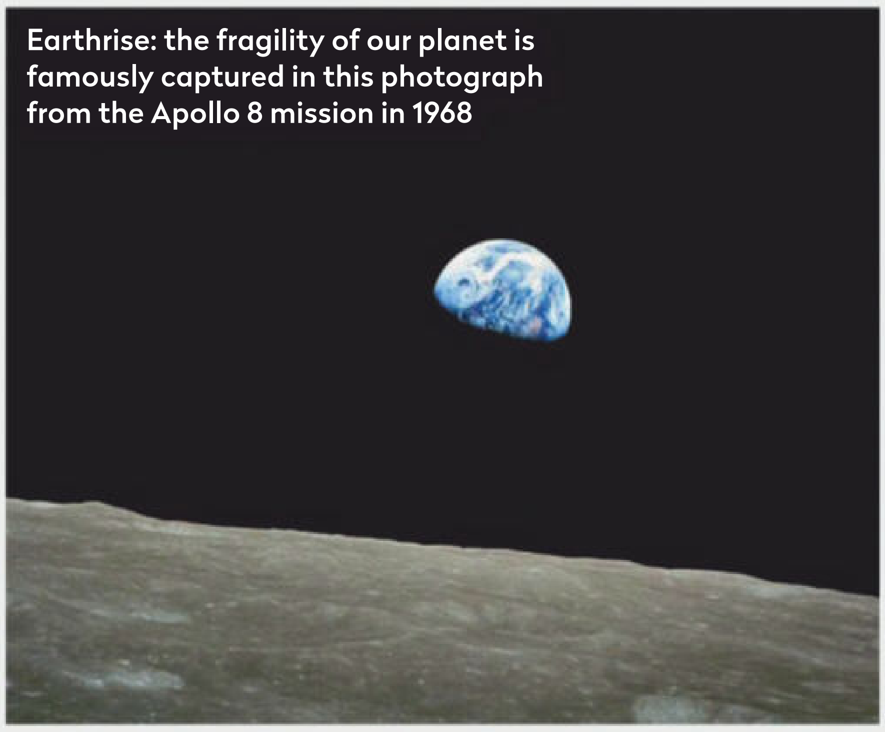
Seeing the world as one

Witnessing our planet from space can have a profound change in attitudes

The overview effect is a term used to describe the profound cognitive shift in awareness and worldview as a result of seeing the Earth from and in space. It was first coined by Frank White in his 1987 book *The Overview Effect: Space Exploration and Human Evolution*. White undertook interviews with 25 astronauts and cosmonauts, and discovered a similar response that came from their experience in space.

His interviewees described the beauty and fragility of the planet and, with their view of our planet as a whole, the concept of nations and conflicts were in turn minimised. What's more, this change in perspective remained with astronauts and cosmonauts during their life.

Although he died before the term was coined, the words of the first human in space, Yuri Gagarin, provide a profound exemplar of the overview effect, when he said: "Circling the Earth in my orbital spaceship, I marvelled at the beauty of our planet. People of the world, let us safeguard and enhance this beauty, and not destroy it." Astronomers must take these lessons and share their concept of peace and protection.



Earthrise: the fragility of our planet is famously captured in this photograph from the Apollo 8 mission in 1968

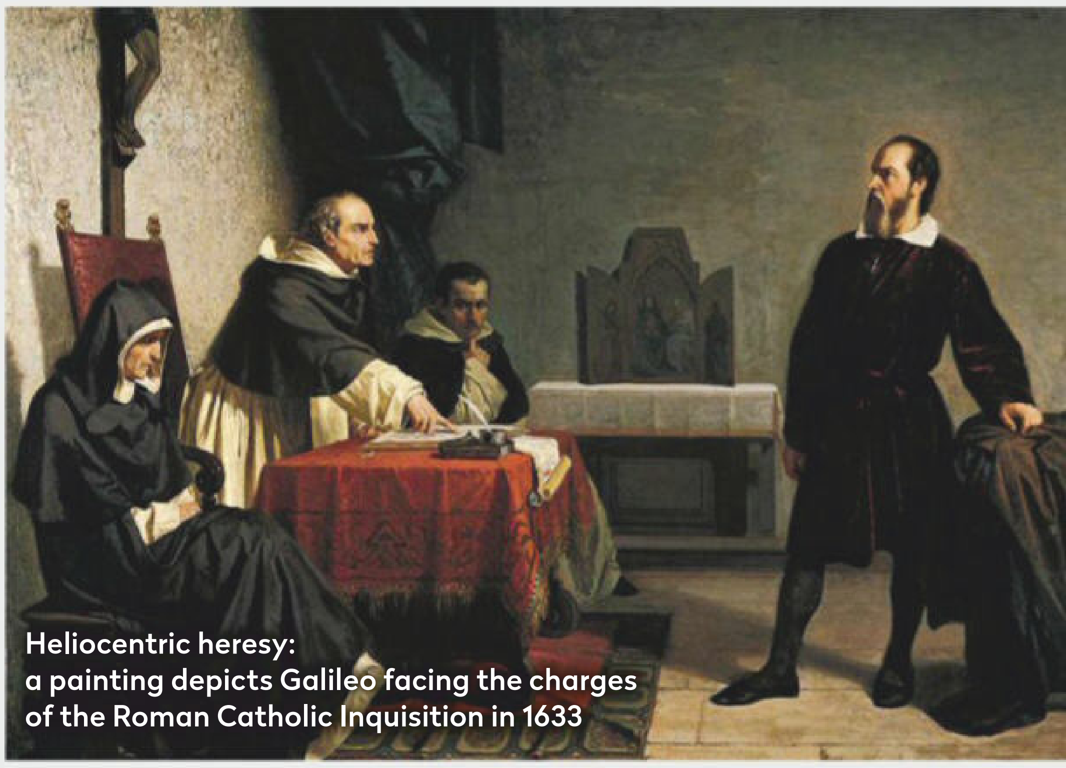
Standing up for science

Through the ages, astronomers have championed scientific findings

In spite of overwhelming evidence, climate sceptics continue to question the role of humanity in global warming. As scientists, astronomers need to reiterate the strong findings on climate change from the scientific community. Astronomers have a history of advocating for science at personal risk, and we can take a lesson from this history.

In the 17th century, Galileo Galilei's observations of the phases of Venus and Jupiter's moons provided evidence that contradicted prevailing religious thought about man and God, and our place in the Universe. In 1616 the Roman Catholic Inquisition ruled that the heliocentric idea that Earth orbited the Sun (as proposed by Copernicus in 1543) was heretical, a ruling which held until 1835. While Galileo first complied with the Church's orders, in 1632 he published a book showing support for the planets' motion around the Sun, which led to a charge of suspected heresy and being placed under house arrest for the rest of his life.

Galileo's trial took place after a complaint was filed against him for his support of the heliocentric theory. In 1991, Pope John Paul II confirmed that the Catholic Church had erred in condemning Galileo and he was pardoned in 1992.



Heliocentric heresy: a painting depicts Galileo facing the charges of the Roman Catholic Inquisition in 1633

▸ fragile." The first images taken by Apollo astronauts of Earth rising above the Moon inspired countless individuals to consider our planet in a new light.

Astronomy is based in the scientific method: on observations, measurements and the formulation, testing, and modification of hypotheses. It's at the heart of our discipline along with peer review, collaboration and critique. As scientific evidence about climate change is being challenged and ignored around the world, we must speak up for science and support the evidence around the subject. Indeed, at the roots of astronomy are figures such as Galileo who risked their lives reporting observations that challenged the world view of the time (see box, above).

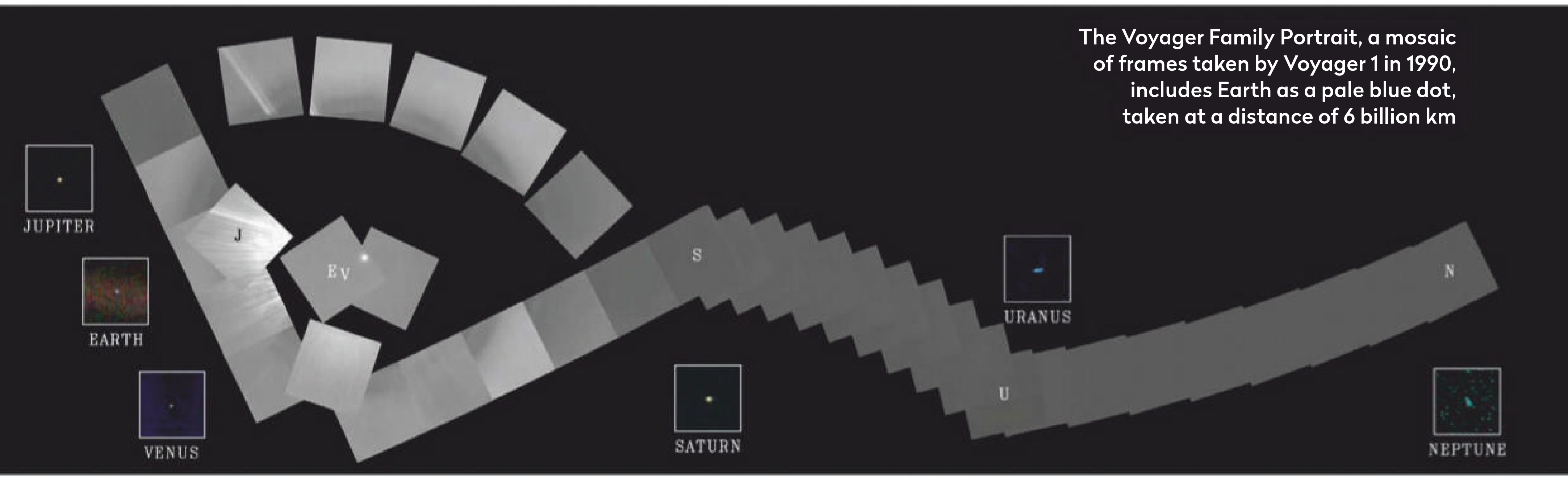
While there are many opportunities to make environmentally friendly changes in our daily lives, as an astronomical community there are a few specific tasks we can do. First, we need to recognise the seriousness of the threat to Earth. While Stephen Hawking and Elon Musk have expressed concern over sending messages to space as a danger to humanity from alien species, we should look at the way we are treating our planet as an imminent concern. We can use our knowledge of the stars and planets to speak out for our environment.

A call to action

Collective action is also important. If you're a member of a local astronomy club, encourage it to advocate for policies that protect the environment. Seek out opportunities to support citizen science initiatives, which contribute to expanding our knowledge and protection of the natural environment and biodiversity. Our planet, after all, is where we spend our time looking up, so we have a vested interest in protecting it.

Darryl Quantz is an amateur astronomer and consultant in public health who looks at the impact of climate change on health and wellbeing

THE PICTURE ART COLLECTION/ALAMY STOCK PHOTO, NASA/JPL



The Voyager Family Portrait, a mosaic of frames taken by Voyager 1 in 1990, includes Earth as a pale blue dot, taken at a distance of 6 billion km

APOLLO 12

Freak lightning strikes meant humanity's second trip to the Moon almost ended before it began, writes **Elizabeth Pearson**

On 14 November 1969, the skies were grey over Florida as the crew of Apollo 12 readied to launch to the Moon. It was raining, it was windy, and the weather was getting worse. Though the crowd that had gathered on the coast was far smaller than the one for Apollo 11, there was one vital person in the audience – President Richard Nixon. Whether his presence or the threat of a month-long delay until the next launch window pushed them on, the mission controllers decided to launch despite the bad weather. At 11:22am local time, the Saturn V bearing Charles 'Pete' Conrad, Alan Bean and Richard Gordon launched and began to climb into the overcast sky.

Thirty-six seconds later, a flash of white light surrounded the rocket. Inside the cockpit, dozens of warning lights lit up at once. Though the crew had run through every imaginable failure scenario during training, none of them had ever seen so many fault alerts activated at once. Sixteen seconds after the first flash, a second one hit. The lights on the instrument panel went dead.

"I don't know what happened here," Commander Conrad called into Mission Control. "We had everything in the world drop out!" Conrad had just a few minutes to decide whether to abort the mission. Despite everything, Apollo 12 was still flying in the right direction, and so he waited, his hand hovering over the abort control.

The rocket's data was a garbled mess, but it was a garbled mess that – back at Mission Control – John Aaron, the environmental control engineer responsible for the ship's electrical systems, recognised. A year before, he'd seen the same error during a training exercise. He'd taken the time to

NASA X 10

MISSION BRIEF

Launch date: 14 November 1969

Launch location: Launch Complex 39 A

Landing location: Ocean of Storms

Time on surface: 1 day, 7 hours, 31 minutes

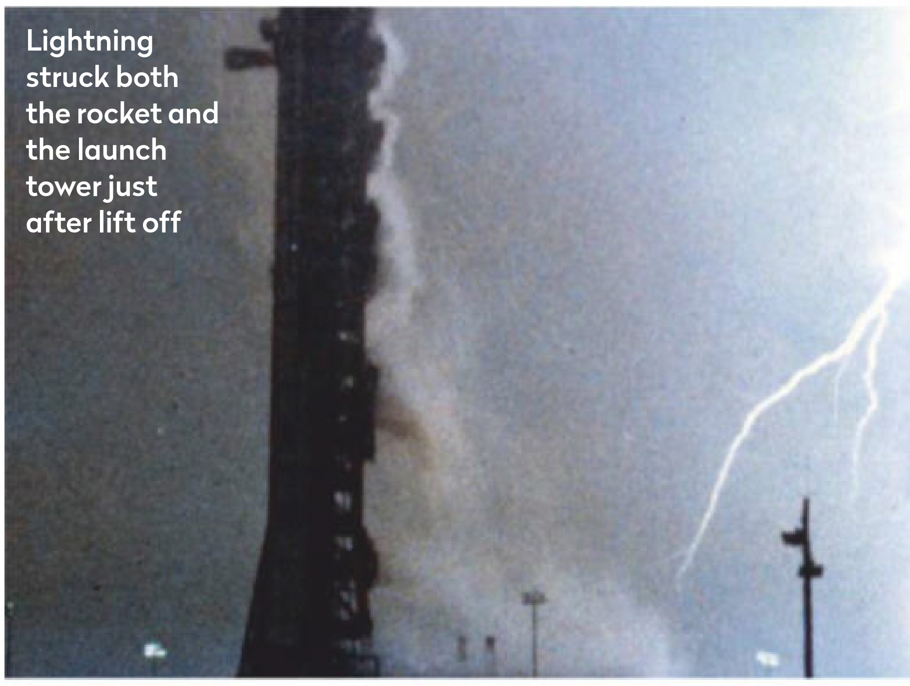
Duration: 10 days, 4 hours, 36 minutes

Return date: 24 November 1969

Main goals: scientific exploration of the Moon; colour TV broadcast from surface

Firsts: multi-EVA surface mission; return to a space probe; human to fall over on the Moon

Scientific instruments: Seismometer; magnetometer; solar-wind detector; suprathermal ion detector; cold cathode gauge (measures tenuous lunar atmosphere)


Lightning struck both the rocket and the launch tower just after lift off


Pete Conrad exits Intrepid onto the lunar surface, on 19 November 1969

track down the problem and, more importantly, worked out how to fix it.

"Try SCE to AUX," he said, directing them to switch the Signal Conditioning Equipment, which translated between the spacecraft's instruments and its displays, to the auxiliary back-up.

The crew had just a few moments to track down the obscure switch among the hundreds on the control panel. Fortunately, lunar module pilot Alan Bean knew exactly where it was. He flicked the switch and the panel lit back up. The mission was saved. Realising that the spacecraft had been struck by lightning, Conrad jokingly requested that NASA "do a little more all-weather testing" before the next mission.

His jovial reaction to near disaster was typical of the Apollo 12 crew. The trio were well known around NASA for being the tightest knit of all the Apollo crews, acting more like brothers than colleagues. For the next three days, the crew laughed and joked their way through their tasks as they journeyed onwards to the Moon.

"Those rocks have been waiting four and a half billion years for us to come grab them" – Alan Bean

Revisiting Surveyor 3

On 18 November, the crew arrived in lunar orbit. Conrad and Bean prepared to make their landing, leaving Richard Gordon to orbit in the command module, named Yankee Clipper. Although Apollo 11 had come down just 4km from its target landing site, the flight planners were certain they'd learned enough to now make a landing with pinpoint accuracy. They were so confident that they decided to visit an old friend – the Surveyor 3 robotic lander, which had scouted the site in 1967. Confidence paid off and the pilots managed to bring down the lunar module, Intrepid, just 182m away from Surveyor 3.

After a short rest, it was time to exit onto the surface, though the occasion was slightly more irreverent than Apollo 11's had been. "Whoopee!" Conrad shouted as he reached the lunar surface. "Man, that may have been a small one for Neil, but that's a long one for me."

Conrad's boisterousness, however, extended into how he walked across the lunar surface, and he soon earned the dubious honour of becoming the first person to fall over on the Moon.

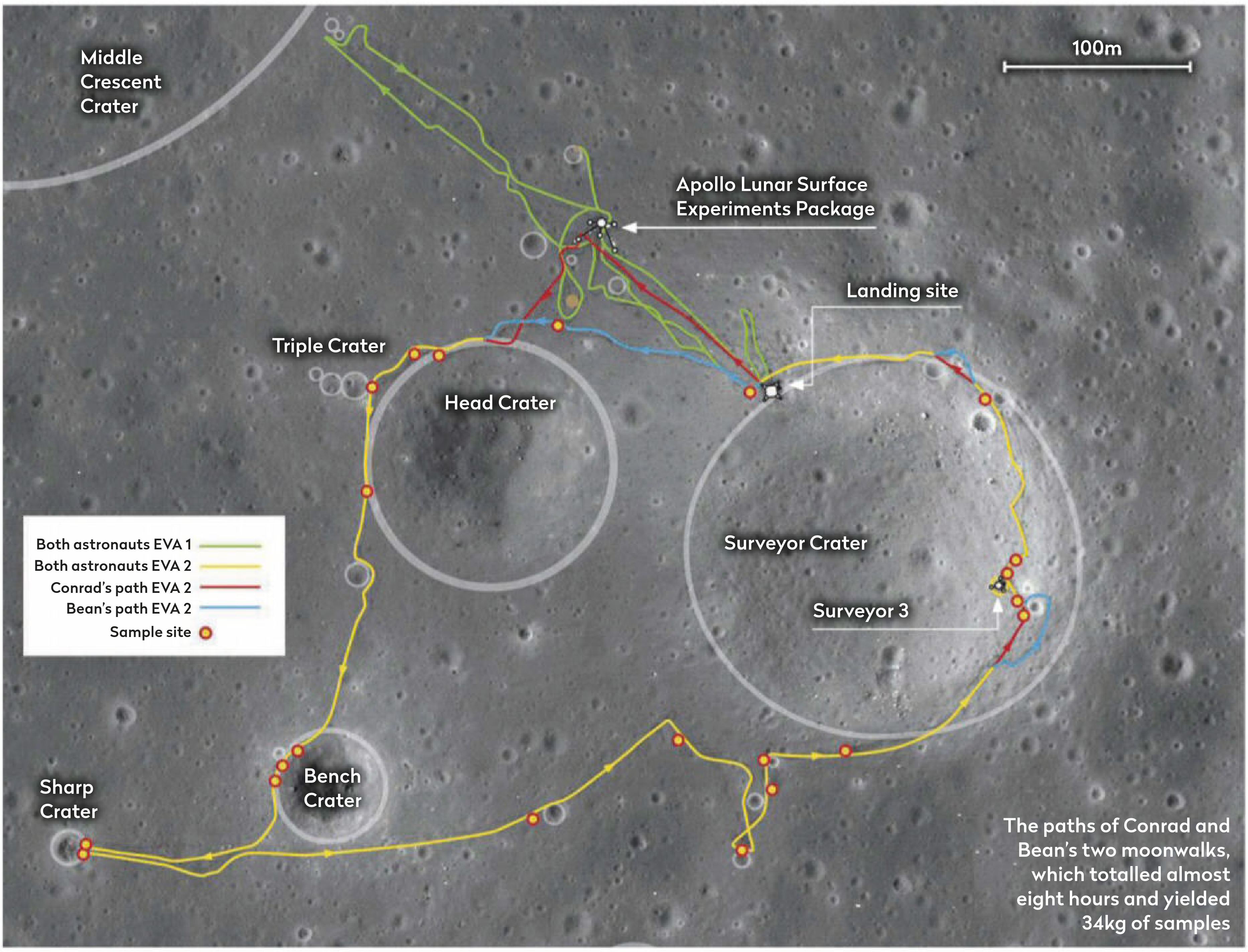
Fortunately for him, the incident wasn't captured on film. Unfortunately for the rest of the world, this was because the pair had destroyed the colour TV camera that was supposed to broadcast their moonwalk. During set up, the camera had accidentally been pointed at the Sun, destroying its sensor. The pair did manage to successfully set up the Apollo Lunar Surface Experiments Package ▸

Meet the astronauts

Commander: Charles 'Pete' Conrad Jr
Conrad started his aviation career in the US Navy before becoming one of the Mercury Seven astronauts, despite rebelling against invasive medical checks by delivering his stool sample in a box tied with a bow. Before Apollo he flew two Gemini missions, and later took part in Skylab 2. He died on 8 July 1999, following a motorcycle accident.

Command module pilot: Richard F Gordon Jr
Gordon joined the Navy in 1953, becoming a test pilot before joining NASA in 1963. He and Conrad had been friends for many years, having met as roommates on USS *Ranger* and serving together on Gemini 11. After Apollo he helped to design the Space Shuttle before retiring in 1972. He passed away on 6 November 2017.

Lunar module pilot: Alan L Bean
Bean joined NASA alongside Gordon in the 1963 astronaut class. Apollo 12 was his first space flight, after which he took part in the Skylab 3 mission. He left NASA in 1981 to become a painter, creating scenes from his moonwalk and often working small pieces of his moondust-stained mission patches into the paint. He died on 26 May 2018.



The paths of Conrad and Bean's two moonwalks, which totalled almost eight hours and yielded 34kg of samples

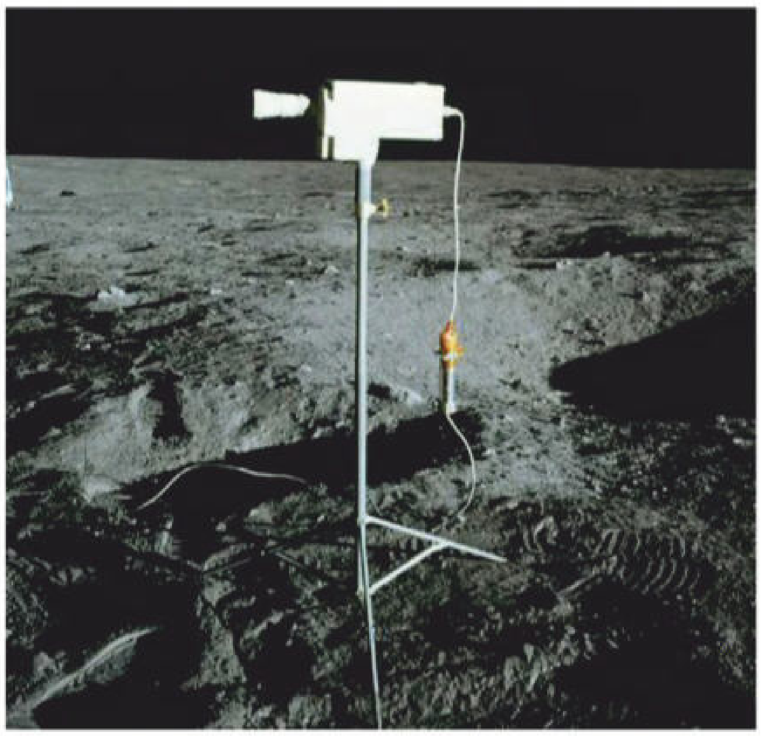
▸ (ALSEP), a set of experiments that would keep running after they'd left the Moon behind.

After four hours on the surface, the duo returned to the module to sleep. They had to do so in their space suits, as removing them risked letting the highly abrasive (not to mention chafing) lunar dust into the suits' delicate joints. Once recovered, they ventured out on a second lengthy excursion, taking numerous samples before walking over to where Surveyor 3 was perched on the edge of a crater. This was the first, and so far only, time humanity has revisited a robotic probe after it's landed. Wanting to test the long-term effects of solar radiation and exposure to space on the probe, the astronauts unbolted several pieces of the spacecraft to take home for analysis.

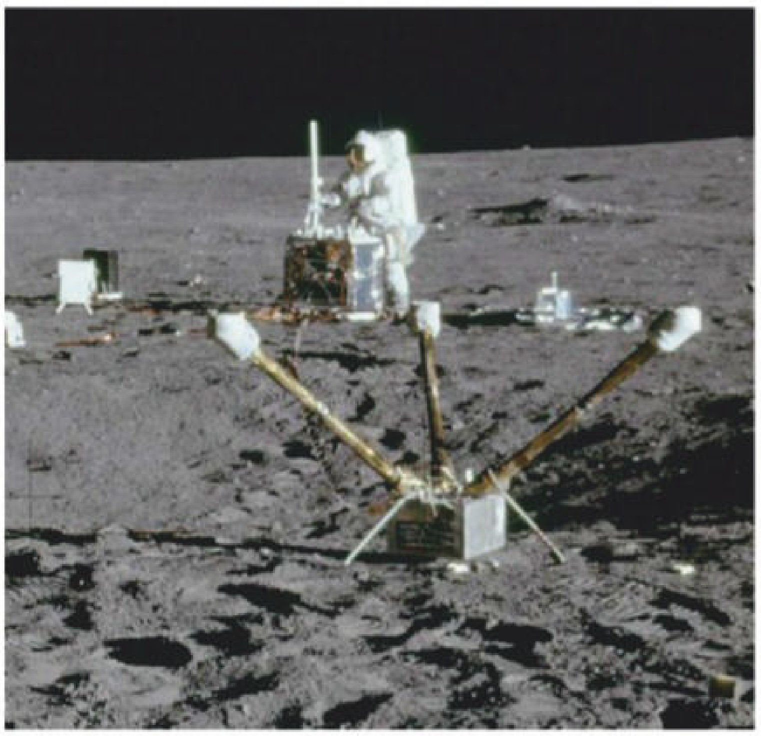
The mission now done, the pair returned to the lunar module before launching off the surface to reunite with Gordon. Four days later they were

"Man, they weren't kidding when they say things get dusty" – Pete Conrad

NASA X 5, NASA GODDARD/ARIZONA STATE UNIVERSITY, EVA PATH DIAGRAM BY PAUL WOOTTON



▲ The broken camera that dashed TV network plans to show the first colour footage of the Moon



▲ Commander Conrad sets up the Apollo Lunar Surface Experiments Package (ALSEP) during the first EVA

Dr Elizabeth Pearson is *BBC Sky at Night Magazine*'s news editor. She gained her PhD in extragalactic astronomy at Cardiff University

MISSION TIMELINE

14 Nov 16:22
Apollo 12 launches and is struck by lightning after 36 seconds and again 16 seconds later

14 Nov 19:15
The capsule leaves Earth orbit

14 Nov 19:40
The command module Yankee Clipper separates from the launch vehicle then extracts the lunar module, Intrepid

18 Nov 03:47
Burn to enter lunar orbit begins

19 Nov 04:16
Lunar module disconnects from command module and descends towards surface

19 Nov 06:54
Intrepid touches down on the lunar surface

19 Nov 11:32
First moonwalk, lasting 3 hours 56 minutes

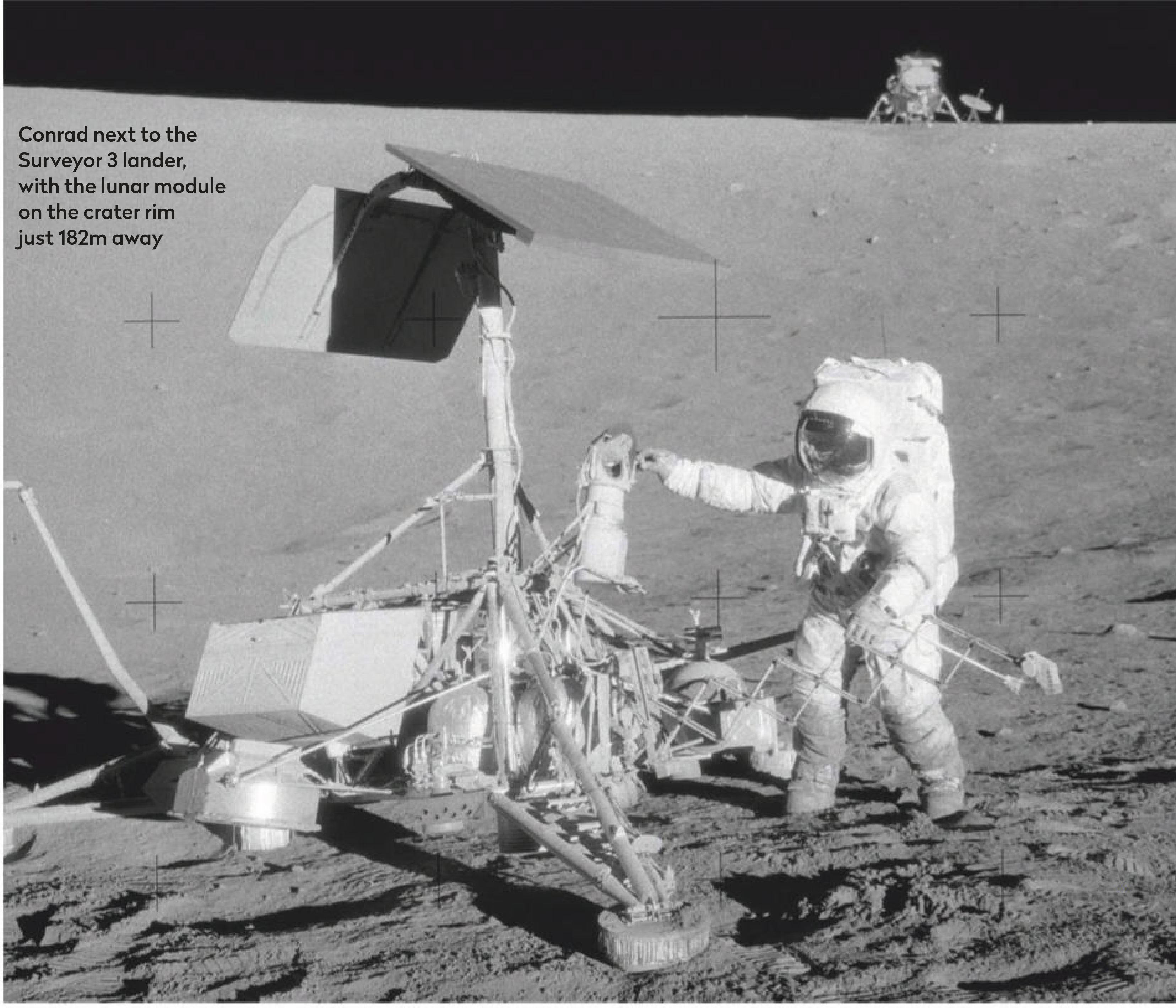
20 Nov 03:54
Second moonwalk, lasting 3 hours 49 minutes

20 Nov 14:25
Lunar module takes off from the Moon's surface

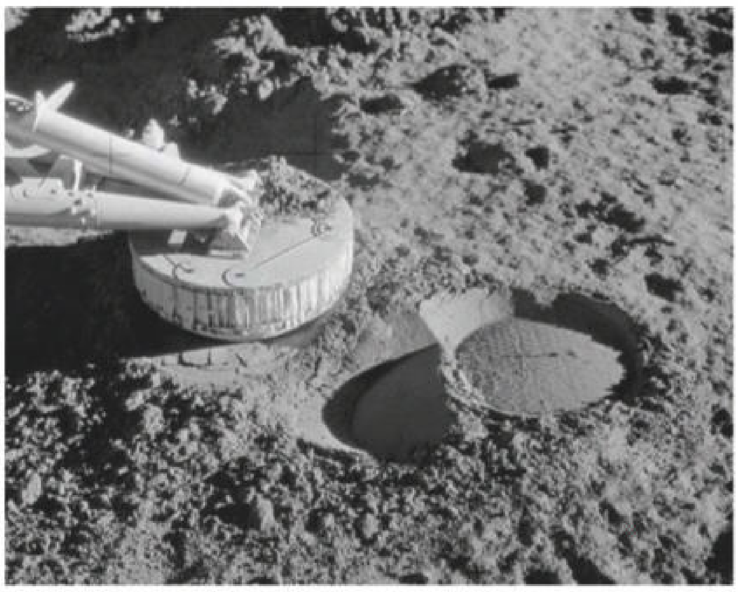
24 Nov 20:53
Despite fears of lightning damage, the parachutes open as expected after re-entry

24 Nov 20:58
Crew splashdown 800km east of American Samoa

All times are GMT.



Conrad next to the Surveyor 3 lander, with the lunar module on the crater rim just 182m away



▲ **A close-up of Surveyor 3's landing pads revealed an imprint showing that it had bounced upon landing**

▲ **There was relief when Apollo 12's parachutes proved to be undamaged by the lightning strikes**

preparing to re-enter Earth's atmosphere. While the crew themselves were calm, back in Mission Control things were a lot more tense. There was a chance the lightning strikes during take-off had prematurely released the landing parachutes. If so, they wouldn't work properly, and the crew would plunge to Earth and certain death. Knowing there was no way to fix such a fault, NASA had kept the information from the crew.

A lost opportunity

The ground crew could only watch and hope as Yankee Clipper fell towards Earth. Fortunately, nine minutes into its descent, right on cue, the parachutes deployed. The capsule splashed down in the choppy Pacific Ocean, and the crew were recovered by USS *Hornet* shortly afterwards.

The mission had been a success, but it had been one tinged with failure. Several magazines of photographic film had been lost or damaged, not to mention the accidental destruction of the colour camera. Both losses were a blow to scientists hoping to study the images, but the latter held far more dangerous consequences for the future of Apollo. TV networks had cleared their schedules and sold advertising slots to show the first live colour footage of a moonwalk, only to end up with nothing to broadcast. With public interest beginning to wane, there was already talk of cancelling the later Apollo missions, and the voices of the project's many opponents were growing louder.

To get things back on track, NASA could only hope things would go better during their next mission – Apollo 13.

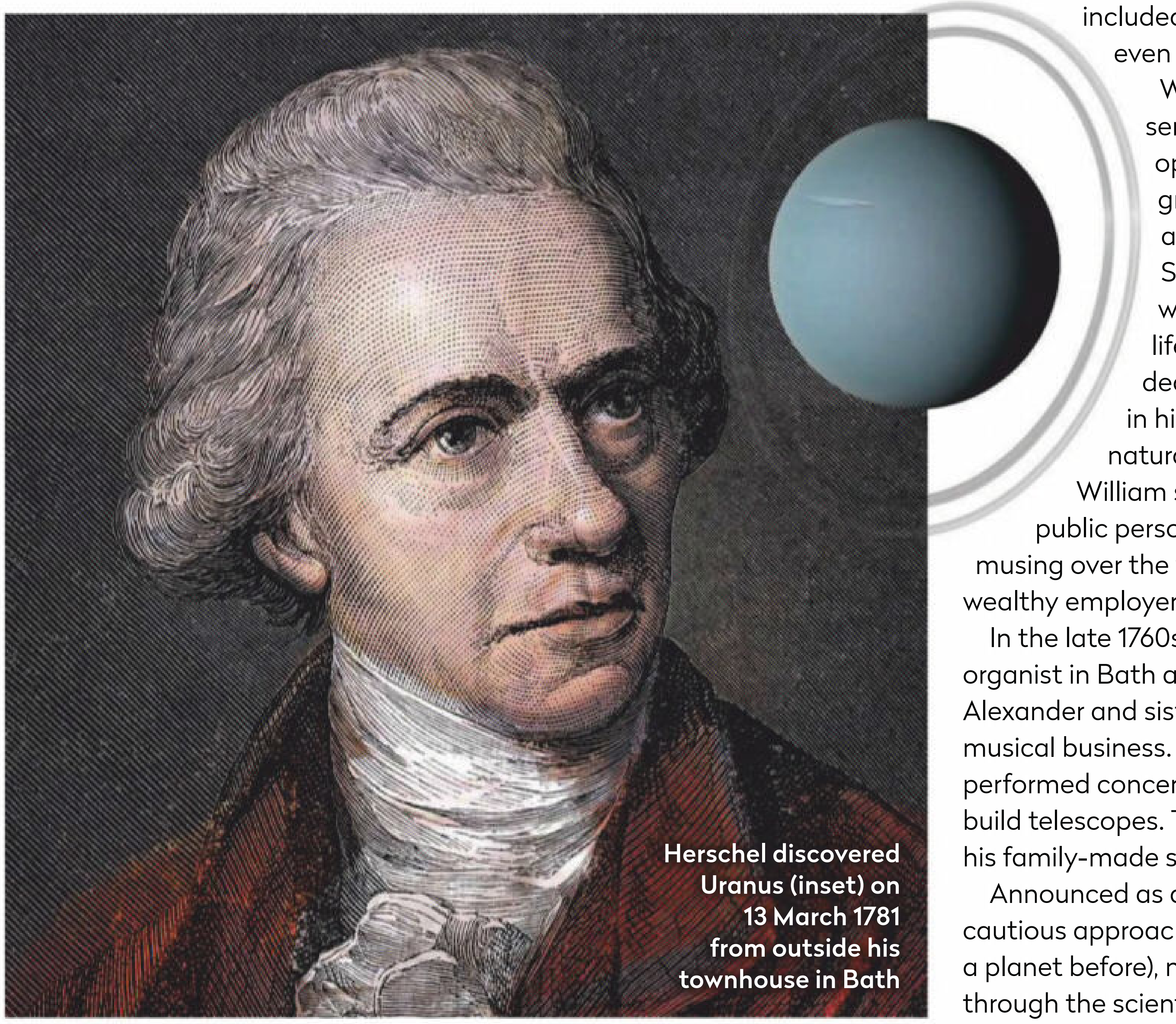
The fundamentals of astronomy for beginners

EXPLAINER

ASTRONOMERS YOU SHOULD KNOW ~NEW SERIES~

Sir William Herschel

The astronomer who went looking for comets and found a plant



Herschel discovered Uranus (inset) on 13 March 1781 from outside his townhouse in Bath

Discoverer of the planet Uranus, pioneer of sidereal astronomy and designer of what was the world's biggest reflector from 1789 to 1845, William Herschel is certainly a name for anyone interested in astronomy to know.

William Herschel was born in Hanover (in modern-day Germany) on 15 November 1738. His was a large, poor, musical family with aspirations. His father was a self-taught musician, who earned his living playing with a local military band; his mother a busy, illiterate, matriarch who took on sewing to make ends meet. At home William and his brothers received an intensive musical education; at school they were the beneficiaries of reforms that ensured they, unlike their parents, received an academic education that included reading, writing, arithmetic and even French.

When William was 19, his parents sent him to England, not only because opportunities for musicians were greater there than in Germany, but also to keep him safe during the Seven Years' War (1756–63). He got work, but found the uncertainty of life as a musician troubling. For a decade he worked as a musician while, in his spare time, educating himself in natural philosophy. Ever the performer, William spent these years cultivating a public persona of musician-philosopher, musing over the wonders of the Universe with his wealthy employers.

In the late 1760s he got a more settled job as an organist in Bath and brought over his brother Alexander and sister Caroline to help build his musical business. Together, for another decade, they performed concerts, taught music and began to build telescopes. Then, on 13 March 1781, using one of his family-made scopes, William discovered a planet.

Announced as a comet at first (Herschel took a cautious approach since no one had ever discovered a planet before), news of the discovery spread quickly through the scientific community and around the world. The Royal family wanted to see his planet (later named Uranus); astronomers wanted to see his telescopes and determine if they were as powerful as Herschel claimed. Soon he was given a new job, as Astronomer Royal, moving to Slough to be nearer his Royal patrons and bringing his sister Caroline with him.

Dr Emily Winterburn is author of *The Quiet Revolution of Caroline Herschel: The Lost Heroine of Astronomy*

Discounted objects

Astronomers at the time concerned themselves almost exclusively with our Solar System. Their job, as they saw it, was to measure with increasing accuracy the exact movements and dimensions of the Sun and Moon, planets, asteroids and comets. When they did venture beyond that remit, it was to identify (and so discount) any objects that could easily be mistaken for comets. William and Caroline Herschel, in contrast,

The Herschel family

William wasn't the only famous member of the family...

Alexander Herschel (1745–1821)
William's brother was a musician who helped him build telescopes.

◄ Caroline Herschel (1750–1848)
William's sister was his astronomical collaborator, a discoverer of comets and the first woman to publish with the Royal Society.

John Herschel (1792–1871) ►
William's son, is known to astronomers for completing his father's cataloguing project for the Southern Hemisphere.

John Herschel the Younger (1837–1921)
William's grandson observed and recorded eclipses from India where he was stationed as an engineer.

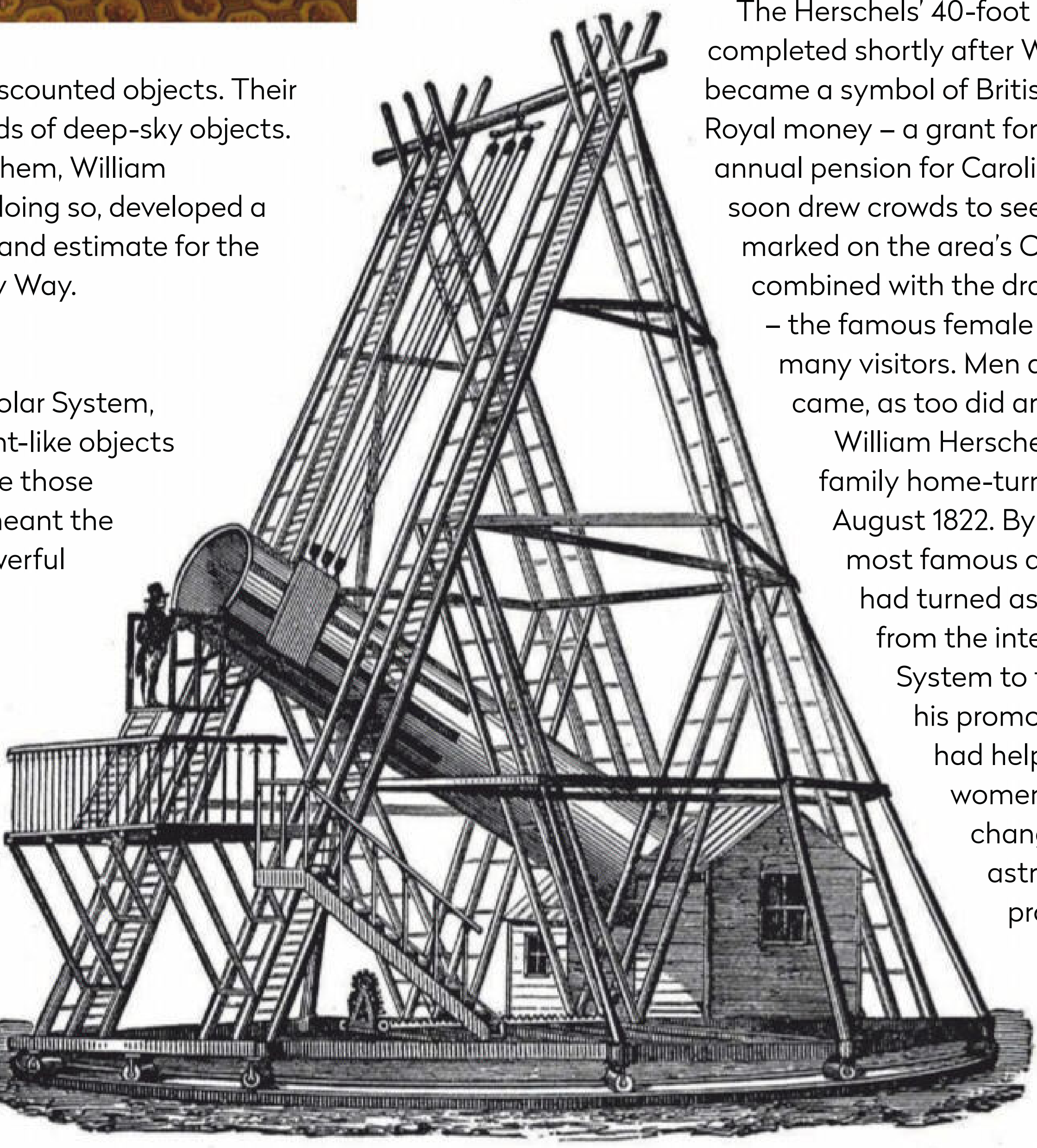
Constance Herschel (1855–1939)
William's granddaughter studied at the University of Cambridge. In later life, she wrote *The Herschel Chronicles*, about the life and work of her grandfather and great aunt.

Planet-spotter: a replica of the astronomer's 7-foot reflector is displayed at the Herschel Museum in Bath

were interested in those discounted objects. Their catalogues listed thousands of deep-sky objects. And not only did they list them, William categorised them and, in doing so, developed a theory of stellar evolution and estimate for the size and shape of the Milky Way.

Grand designs

Looking out beyond the Solar System, to try to resolve these point-like objects and identify and catalogue those that weren't single stars meant the Herschels needed big, powerful telescopes. William had discovered the planet Uranus using his 7-foot long (2,133mm) reflector (copies of which – made and sold by him – can be found in many museums). He also made a 10-foot, 20-foot, 30-foot and finally a 40-foot reflector.



► A drawing of Herschel's 40-foot reflector, also known as the Great Forty-Foot telescope

The Herschels' 40-foot (12,192mm) reflector, completed shortly after William got married, quickly became a symbol of British science. It was built with Royal money – a grant for the building work and an annual pension for Caroline as co-operator – and soon drew crowds to see it in Slough. It was marked on the area's Ordnance Survey map and, combined with the draw of William and Caroline – the famous female comet-hunter – attracted many visitors. Men and women of science came, as too did aristocrats and dignitaries.

William Herschel died in Slough at his family home-turned-observatory on 25 August 1822. By then he was perhaps the most famous astronomer in Europe. He had turned astronomers' attentions from the internal workings of the Solar System to the stars beyond. Through his promotion of his sister's work, he had helped open the door to women in science. He had changed the image of astronomy too, blending the professional's need for large, powerful instruments with the amateur's curiosity and passion for exploration and discovery.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- James Heard, 17, Participant

DIY ASTRONOMY

Model your own realistic lunar crater

Increase your knowledge of a region of the Moon and learn how its shadows change

◄ **Make an impact: the completed model of Archimedes**

Studying the shadows cast by features on the Moon can reveal so much about the structure of the lunar landscape. From the shadows we can see differences in wall height along crater rims and infer the height of crater walls themselves; details that are not apparent under a high Sun angle. If you know the exact angle of the Sun, you can even use basic trigonometry to calculate the height of a feature based on the shadow that is being cast. Building a model crater can become a fantastic teaching tool for outreach sessions and makes a great school project.

It is important to study these features at different Sun angles as the length of the shadows change as the Sun angle changes in association with the changing phases of the Moon. Unfortunately, crater sunrises and sunsets only occur once per lunar cycle (about 29 days), with a sunrise occurring while the Moon is waxing, and a sunset only occurring while its waning. In the real world these times may not coincide with a suitable hour for an outreach session. In addition, observing the shadow changes can take several hours, which isn't practical for most events.

Chasing shadows

If you have a realistic model of a lunar crater, you can easily demonstrate how the shadows change with a torch. This gives an opportunity to teach the activity in a shorter time frame and at a location to suit you.

ALL PICTURES: MARY MCINTYRE

Tools and materials

▶ A shallow box with a lid: a Tupperware container works well as the lid will protect your model when not in use. The one used here measures 29x21.5cm.

▶ Bottle of liquid latex: available from art shops and online stores. Approximately 250ml of latex is enough for this size of container

▶ White baking flour though: any kind of flour will do.

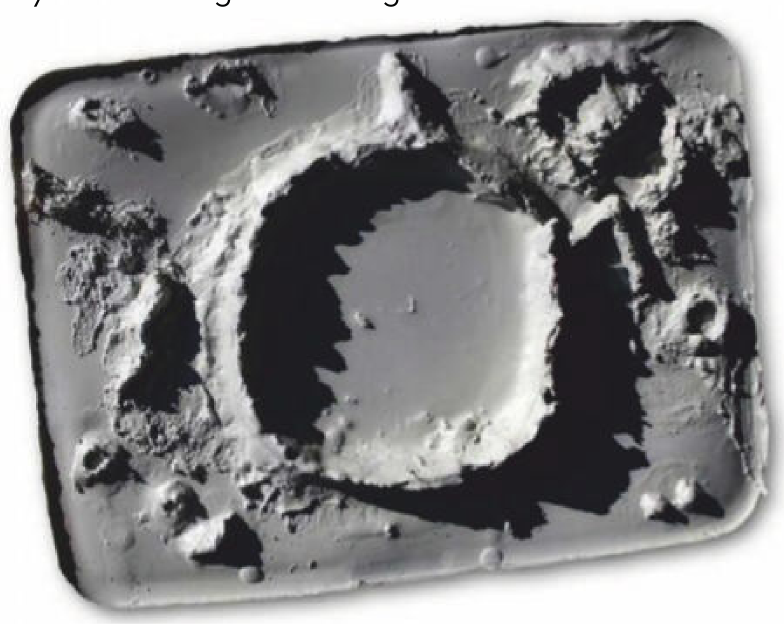
▶ Two mixing bowls and a spoon: glass or plastic bowls are fine as liquid latex peels off easily once dried.

▶ Good reference photo: chose one that shows the entire crater and which has well-defined, visible shadows.

Mary McIntyre is an astronomer and dedicated astro imager based in Oxfordshire

Armed with a small number of basic items and a good reference photograph, it's possible to build your own model of your favourite crater.

It's important to choose a photo that shows well-defined crater shadows, as this will allow you to recreate the correct shapes along the rim. (The image we used is of Archimedes, taken by Craig Howman). The model shows the crater and also the landscape in the area around it. It was created using liquid latex paste, which is made by mixing liquid latex with flour. Latex paste is lightweight and will not break during transportation. Make sure you're working in a well-ventilated area and cover your table with a bin liner. Wear an apron over your clothes and, if you have a latex allergy, ensure you wear gloves. It's helpful to have a bowl of flour on the table so you have easy access to it for mixing the paste. You may find it helpful to have a desk lamp shining from the same side as the Sun in the photo, so you can compare the shadows being cast as you build your crater model. By building your model, you'll be studying the crater and surrounding area in detail and it will help to increase your knowledge of that region. ►



► **Use a torch for side-illumination to simulate shadows cast by the Sun**

Step by step

Step 1

Cover your work area with something in case of spills. Next, ensure your container is on a level surface and pour some liquid latex into it so that the whole base is covered with a thin layer. Allow this to dry to provide the base layer before continuing.

Step 2

Decide how big your crater will be in relation to the base so you can fit all its details on it. Cut out a paper circle and gently draw round it on the latex with a marker pen to act as your guide.

Step 3

Pour some liquid latex into a bowl. Then mix in some of the flour, a little at a time, until you have a paste which can hold its own shape without being too stiff. It's better to work with small batches at a time.

Step 4

Using a spoon, start to add the latex paste onto the base, following the circle you drew in Step 2. Once the circle is completed, note the varying structure in the guide photograph ready for the next step so you can recreate the crater's walls.

Step 5

Pour some liquid latex into a saucer. Dip your fingers or tools into the liquid latex then smooth and mould the shape of the crater working in layers, building up the detail in and around the crater. Dip your tools or fingers into the liquid latex to prevent sticking.

Step 6

Once finished, allow to dry completely for 48 hours. If you want, you can finish it off by painting it white or grey with acrylic paint or matt spray paint (wear a mask if you are spraying). Once dried, you can lift the completed model out of the box.

ALL PICTURES: MARY MCINTYRE

Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY CAPTURE

CAUTION
Never observe or image the Sun with the naked eye or any unfiltered optical instrument

Catch the transit of Mercury

There's a long wait if you miss the planet crossing the Sun's disc on 11 November

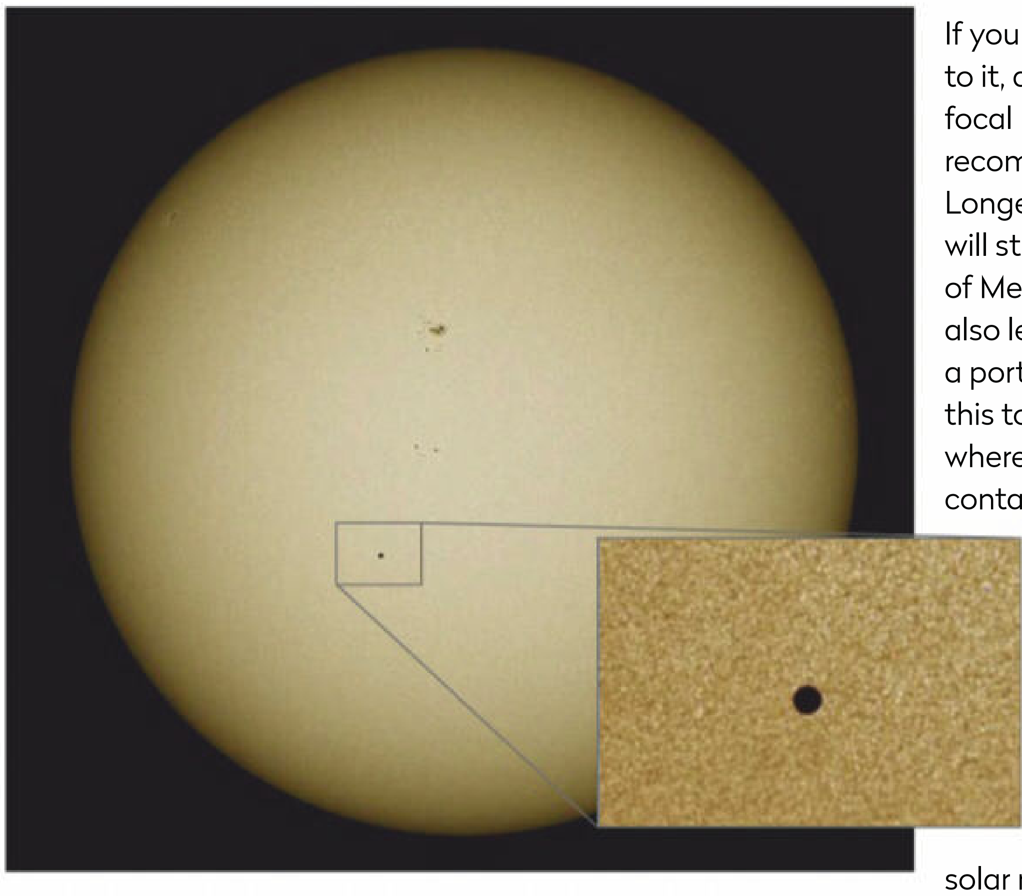
This month's transit of Mercury is an infrequent enough event to make it worth pushing the boat out for. It's weather-dependent, but assuming you do get some clear skies on the afternoon of 11 November, imaging the transit is going to be a high priority. Bear in mind that the next one doesn't occur until 13 November 2032.

If you do get suitable weather conditions, the good news is that the event isn't too hard to image. To do so you'll need a telescope which has been prepared for solar imaging. For white light imaging this will necessitate covering the scope's front aperture with a white light solar filter. This is constructed from inexpensive solar safety film, but pre-made versions are also commercially available.

If your scope has too large an aperture to be cost-effectively covered by the film, consider using thick card over its front opening with a smaller aperture cut within it. For reflectors and catadioptric scopes, offset the hole to one side – referred to as an offset aperture – to avoid having the secondary mirror appear within its boundary. An important and often overlooked element to a solar imaging setup is the finderscope: this must also be filtered, covered or removed completely to avoid damage.

Once the scope is correctly filtered, it's possible to image the Sun in exactly the same way as you would for example, image the Moon. All the white light filter material does is reduce the incoming light to safe levels for your telescope and camera to deal with.

Mercury's silhouetted dot will appear quite small, around three times the apparent diameter of Uranus.



▲ **A focal length of 1,000mm (or above) is needed to define Mercury against the Sun's disc**

If you want to get a decent size to it, a reasonably long effective focal length must be used. We'd recommend at least 1,000mm. Longer effective focal lengths will still give you a larger image of Mercury's black dot but will also leave you looking at just a portion of the Sun's disc. For this to work you'll need to know where Mercury will first make contact with the Sun's limb. Like any astronomical target, imaging the Sun requires precise focus. A dark, high contrast sunspot is best for this, but the Sun has been blank for quite a while as it slumbers during a solar minimum. If no sunspots appear, the Sun's edge is a good substitute.

The Sun's photosphere, its visible surface, is covered in a fine 'rice-grain' pattern called solar granulation. This represents the top of huge convective cells welling up from within its interior. Each cell occupies an area similar in size to the US state of Texas. Divisions between cells have a slight magenta colour bias. Imaging through a green filter (the opposite colour to magneta on a colour wheel) gives these boundary lines better contrast, making them appear darker. If conditions are steady, solar granulation also works as a fine focus guide. Our step-by-step guide (right) shows you how to obtain a record of this infrequent event.

▸ *Turn to pages 30 and 46 for more information*

Pete Lawrence is an expert astro imager and a presenter on *The Sky at Night*

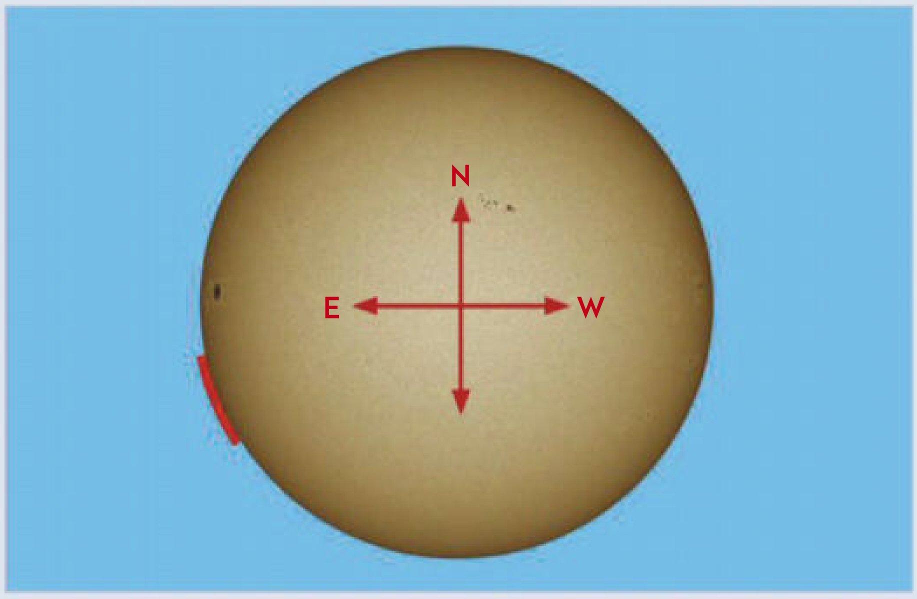
Recommended equipment: A telescope fitted with a certified solar filter; a high frame rate camera

Send your images to:
gallery@skyatnightmagazine.com

ALL PICTURES: PETE LAWRENCE

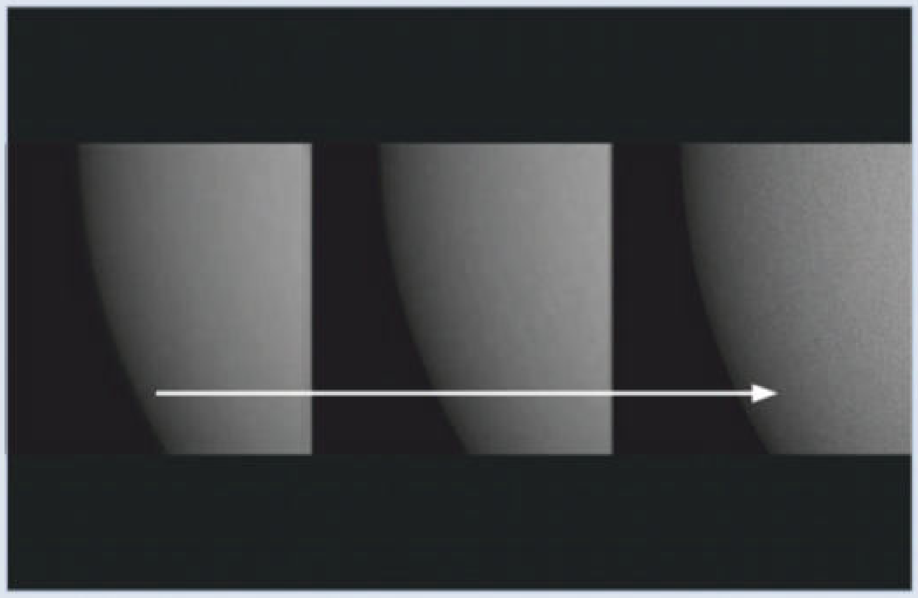
STEP 1

Your telescope has a fixed focal length, but it's effective focal length can be adjusted with an optical amplifier such as a Barlow lens or Powermate. We suggest working with at least 1,000mm for this transit. Increasing the effective focal length with an optical amplifier will increase the size of the dot but also lower contrast.



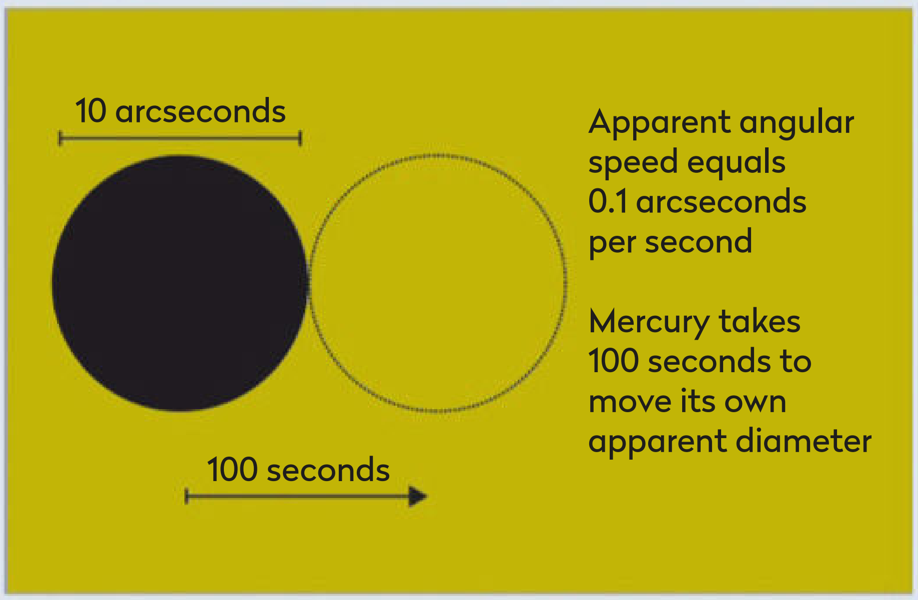
STEP 2

We'd recommend an equatorial mount. Set up for white light solar observing and point the scope at the Sun. If using an image scale which only shows part of the Sun, work out your orientation using our guide on page 46. Determine where the east-southeast limb is prior to the transit's start and centre it in your field of view.



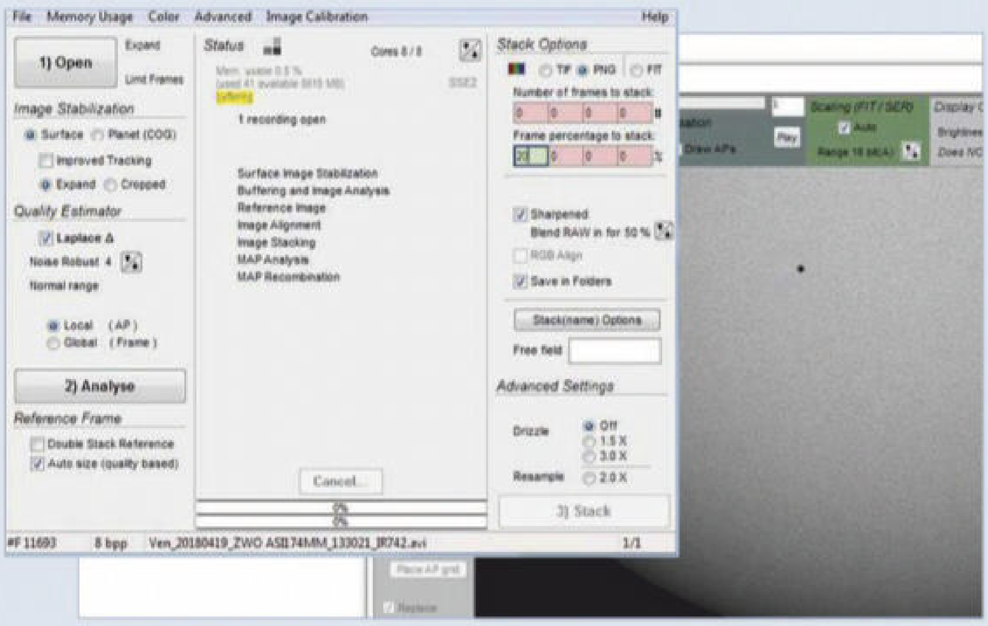
STEP 3

Focus is important so take your time and recheck it during the transit. The Sun remains at a low altitude during November and this means the seeing is likely to be unsteady. The transit starts close to the Sun's highest point in the sky, due south, so this should help. On the flip side, the heat of the day also fuels instability.



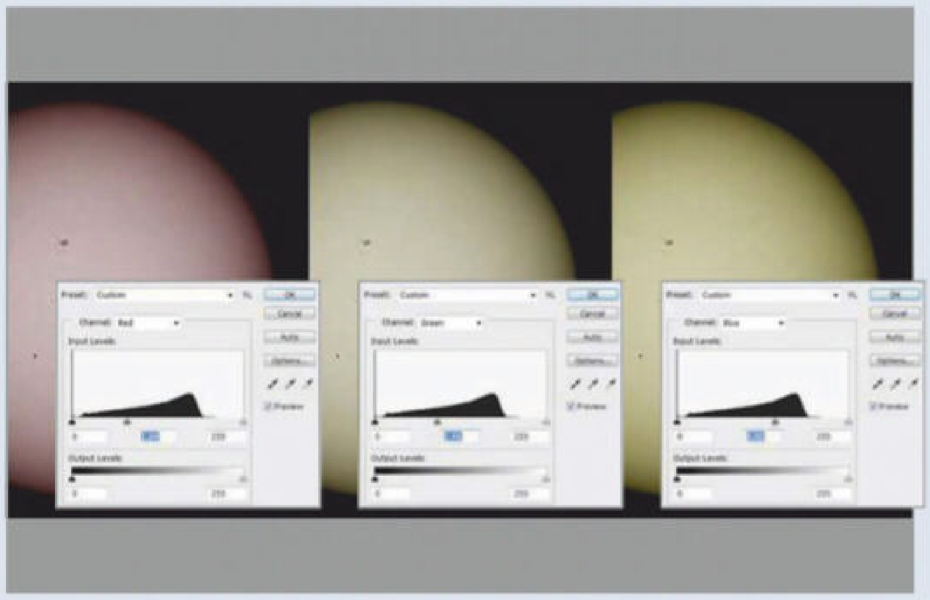
STEP 4

Mercury's apparent speed will be about 0.1 arcseconds per second, so it'll take the planet 100 seconds to move its own 10 arcsecond diameter across the solar disc. Capture times should be as short as possible using as high a frame rate as you can get away with. A 10–20 second capture, with say 800–1,000 frames, is a good target.



STEP 5

Decide beforehand the time intervals between captures. Approximately 220 minutes of transit are visible from the UK so one 10–20 second capture every 10 minutes would be a reasonable target. Process your captures with a registration/stacking application such as AutoStakkert! or RegiStax.



STEP 6

For greyscale results, open in an image editor and save in a lossless format (eg, PNG) as an RGB file. Open the Levels control. Adjust the mid-point slider for the red and green channels towards black, blue towards white. When happy with the colour, note the adjustments. Save as a custom preset to use with the other results.

Expert processing tips to enhance your astrophotos

ASTROPHOTOGRAPHY PROCESSING

Using Photoshop to perfect a crescent Moon

How to combine two images to reveal the Moon's best crescent and earthshine qualities

▲ Whole of the Moon: the final processed Photoshop image

A few days before or after New Moon, the beautiful crescent Moon is visible. Look more carefully and you soon realise that the 'dark' part of the Moon can just be seen feebly illuminated. This is known as earthshine and it's due to light reflecting off the bright Earth back onto the Moon and gently illuminating it. The glorious naked-eye view of the Moon's crescent – with the dark portion of the disc illuminated by earthshine – looks absolutely spectacular, but capturing that moment on camera is much more problematic.

The box of three images (right) illustrates the point quite clearly. A short exposure, like the first image on the left, captures the detail in the bright crescent while the earthshine is too faint to be seen. The middle image shows a longer exposure which brings out the earthshine, but in the process over-exposes the bright crescent and any detail on it is lost. It's a real catch-22 situation. Ideally, we'd like to be able to show both at once, to produce a view like the final image on the right.

There is a way to do this by taking two images and combining them digitally to create a composite image. This is carefully combined to get the best of both exposures without it looking false and poorly processed. Unlike other methods this produces the least intrusive artefacts and is relatively easy to do.

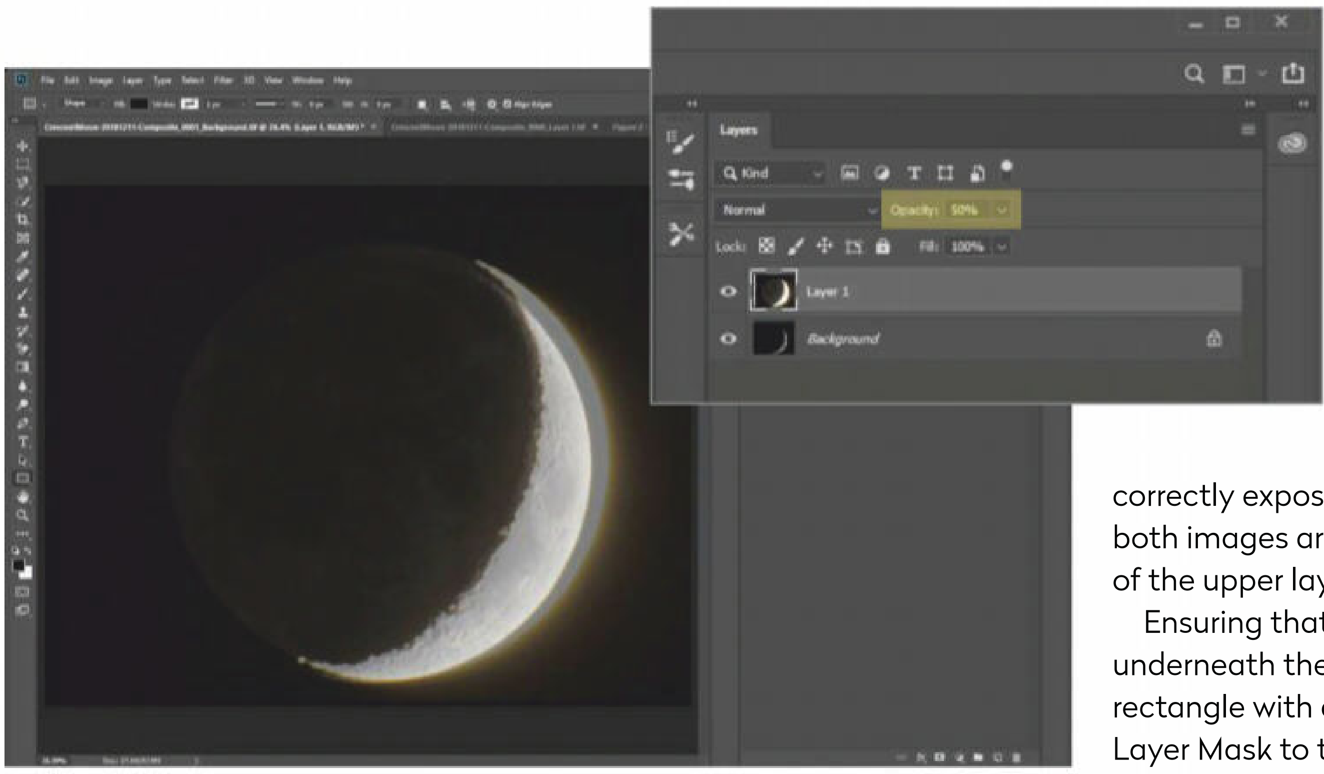
A combined effort

The first step is to take images similar to the first two shown in the box (below). In this guide we are using Adobe Photoshop, so open both your images up in the software. Select the over-exposed image with the earthshine visible and from the menu click Select › All (or Ctrl-A) to select the whole image. From the menu then click Select › Edit › Copy (or Ctrl-C) to copy the image into the clipboard. Next, select the under-exposed image. From the menu, click Edit › Paste (or Ctrl-V). A copy of the over-exposed Moon will be pasted on top of the other image as a new layer.

Now we need to align these two images. From the menu click Select › Window and make sure Layers is ticked, to reveal the layers panel. The small icons show the contents of the image held in both layers. Click on

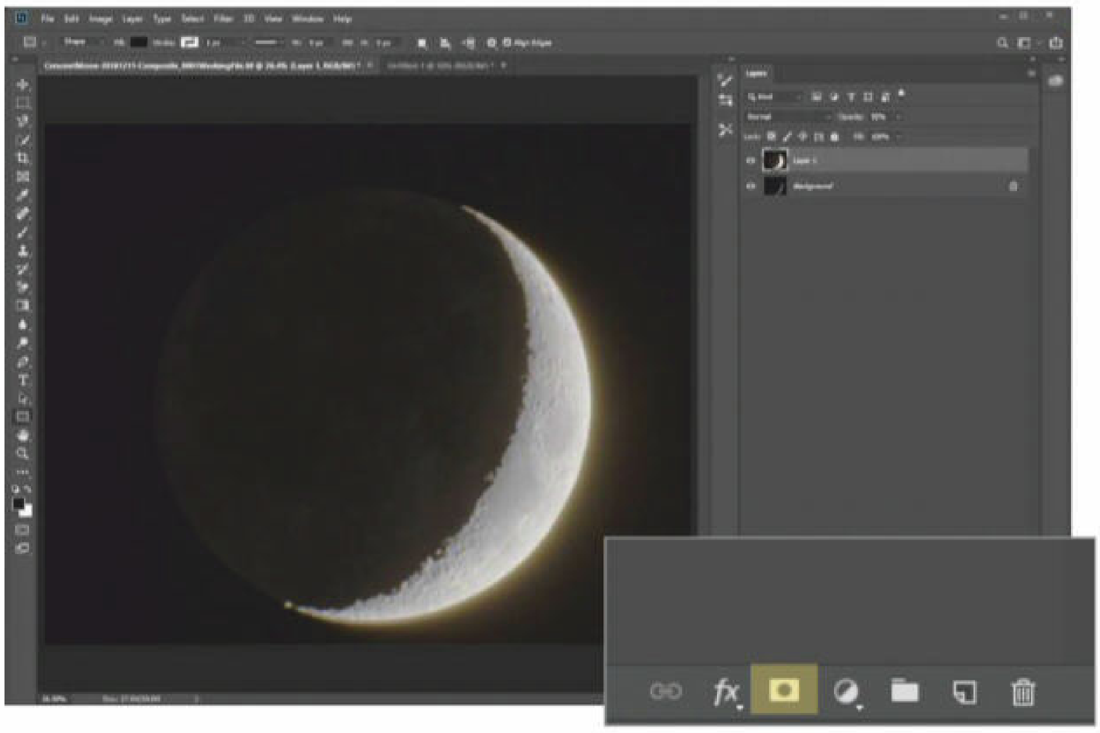
▲ Best of both worlds: (left to right) a short exposure of a crescent Moon; a long exposure with earthshine; a composite of both images processed in Photoshop

ALL PICTURES: DAVE EAGLE



◂ Overlay your two images and adjust the Opacity level of the upper image to 50% to help you align it with the image below

◂ Once the Opacity level is restored to 100%, a Layer Mask can be added



▴ To add a Layer Mask to the aligned images, select the Layer Mask button – a white button with a black dot in the middle

the upper layer to select it and click the dropdown menu called Opacity. Next, slide the Opacity to 50%. The image underneath can now be partially seen.

Select the Move tool and then hold down the mouse and move the upper image until the two images are correctly in register. Don't worry if the over-exposed limb of the crescent overlaps the correctly exposed portion, as this is expected. When both images are exactly aligned, change the Opacity of the upper layer back to 100%.

Ensuring that the upper layer is still selected, underneath the Layers palette, click the white rectangle with a black dot in the middle. This adds a Layer Mask to the upper layer.

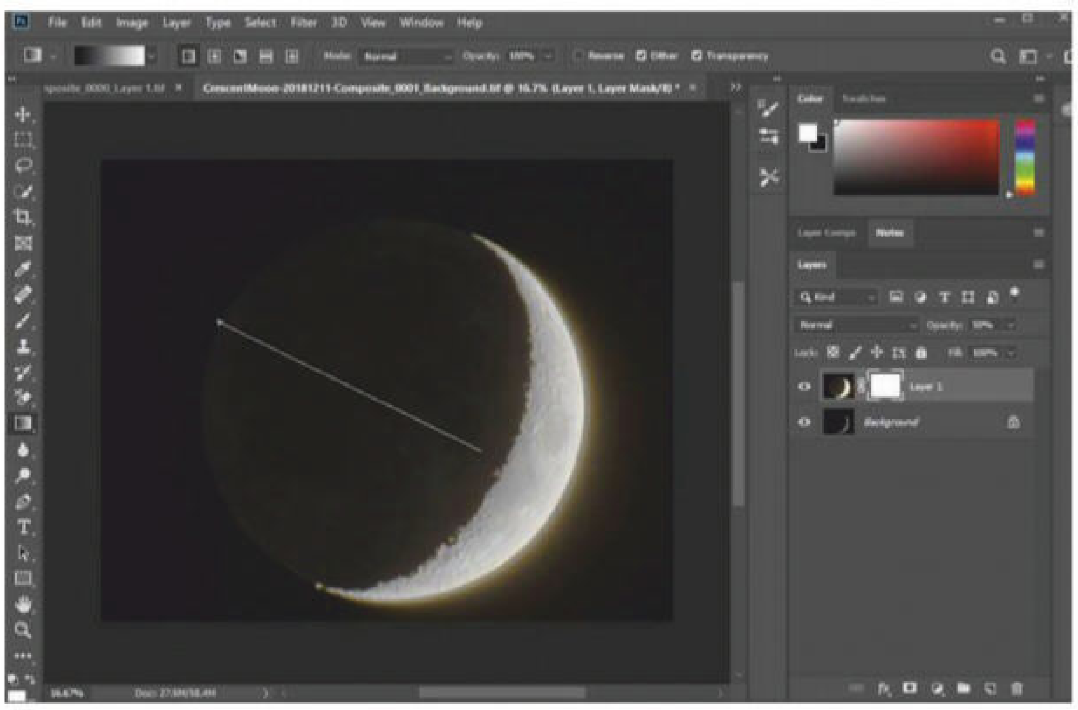
Finishing touches

This Layer Mask is now visible in Layers as a white icon next to the icon of the upper image. A gradient of brightness across the Layer Mask needs to be added, so that we can hide parts of the bottom image that we don't want and reveal what we wish to retain. This will help to achieve the composite image. From the Toolbar menu select the Gradient tool. If it is hidden, right click the mouse to reveal it and then select it. Make sure that Layer Mask is still selected. It will have four 'corners' around it. Hold the mouse over the image close to the edge of the limb of the earthshine Moon and left click. Keep the mouse button pressed and draw a straight line towards the bright crescent, releasing the mouse a little before reaching the bright crescent.

Release the mouse button. The correctly exposed crescent should now be visible. The gradient of light and dark running across the Layer Mask allows us to see through to part of the bottom image to view the faint earthshine, but hides the over-exposed crescent. This may need to be repeated several times to get the best result.

There is a drop off in earthshine brightness the closer the earthshine gets to the crescent, due to the gradient that was used to obtain this result. But it is a small price to pay for getting this great effect. For final adjustments, on each layer, adjust the curves to get both background levels more evenly matched. Adjust the brightness of the earthshine, or even add some more saturation to the image to really bring it to life. Flatten the image to remove all the layers and save the final image as a new file.

Once saved, your final processed picture will bring out the best qualities of the earthshine and the crescent.



◂ Create a Layer Mask Gradient to hide and reveal parts of the image below

Dave Eagle is an amateur astronomer, planetarium operator, presenter and author

Your best photos submitted to the magazine this month

ASTROPHOTOGRAPHY GALLERY

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PHOTO OF THE MONTH

△ Chasing the Moon

Alessio Vaccaro, Cefalù, Sicily, Italy, 26–27 August 2019

Alessio says: "It took 100 shots, taken over the course of 90 minutes, to capture the movement of the Moon against the stars in the background. It was a real challenge but the end result was more than worth it. I had to make sure that the telescope was perfectly tracking the Moon at each shot and, because of the unusual star trails, I had to align the frames manually rather than with automatic tools."

Equipment: Canon EOS 5D camera, TS Optics 80/480mm apo refractor, Sky-Watcher HEQ5 mount
Exposure: ISO 1600, f/6, 4", no filters
Software: Python, Photoshop

Alessio's top tips: "Images like this are obtained through a lot of practice, patience and resistance to the cold. This photo required over 20 hours of work to find the right location, prepare the equipment, capture the shots and process them. Though you'd normally use an untracked mount to capture star trails, in this case a motorised tripod that compensates for the Moon's motion was vital to keep the frame fixed on the subject. The trails were created by using software to combine the shots later."

△ Pickering's Triangle

László Bagi, Öcsöd, Hungary, July–August 2019

László says: "Pickering's Triangle makes a great shot from Hungary because of its favourable position during summer. I used filters to capture the layers of hydrogen and oxygen that ionise in the fog, and worked the layers together to make the final photo. The colours of the stars were captured using RGB filters. I was taken aback by the end result."

Equipment: Atik One 6.0 Mono camera, Newtonian astrograph 200/800 f/4 telescope (custom-built)
Exposure: Ha 9 hours, OIII 9 hours, RGB 60'
Software: Photoshop, RegiStar

△ Solar eclipse spectra

Robert Slobins, Las Flores, Argentina, 2 July 2019

Robert says: "The brighter lines are hydrogen (red, blue) and helium (yellow). The faint red ring left of the red hydrogen line is iron with nine electrons missing (Fe X). We also often see a more intense green ring of iron with half the electrons missing (Fe XIV), but it can't be seen here."

Equipment: Nikon D800 DSLR camera, Nikkor 180 f/2.8 lens **Exposure:** ISO 200, 1/15" **Software:** Capture One

◁ Cocoon Nebula, IC 5146

David Wills, Granada, Spain, 2–6 August 2019

David says: "Imaging the Cocoon Nebula was a four-night project at my remote site at Spain's PixelSkies. I was pleased with the way the image turned out, but I was surprised at how much hydrogen-alpha there was in the background."

Equipment: Starlight Xpress Trius SX-694 Mono camera, Tec 140 F7 telescope, iOptron CEM60 Go-To mount, Astronomik LRGB and Ha 6nm filters **Exposure:** L 33x900", R 8x900", G 14x900", B 8x900", Ha 19x1,200" **Software:** Sequence Generator Pro, PixInsight, Photoshop

△ Delta Aquarids

Omid Qadrdan, Khour va Biabanak, Iran, 24 July 2019

Omid says: "The Delta Aquarid meteor shower is hard to see from the Northern Hemisphere but I found a place with an open horizon that was free from light pollution and hoped for the best. Then suddenly there it was: a beautiful light blue fireball appeared in the sky. It was amazing."

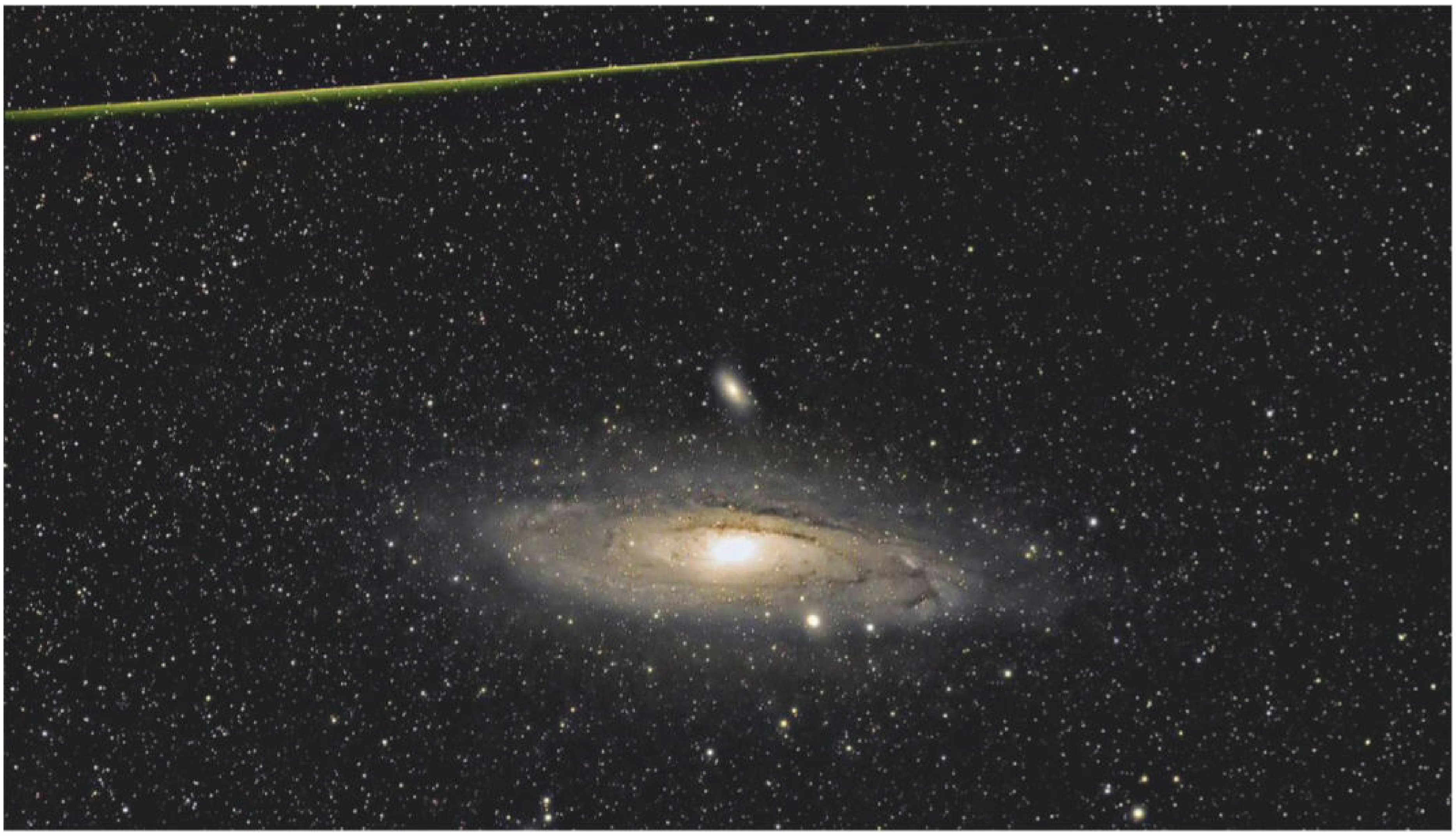
Equipment: Fujifilm X-E2 camera, Samyang 12mm f/2.0 lens **Exposure:** 1x30" **Software:** Photoshop

◁ Wizard Nebula, NGC 7380

Ross Clark, Whitley Bay, 24–25 August 2019

Ross says: "The Wizard Nebula's hydrogen-alpha emissions are well suited to the filter I'm using from my light-polluted garden. I was pleased with the outcome, especially the fainter emissions filling the field of view."

Equipment: ZWO ASI1600 MC Pro Gain 200 camera, Lacerta 72/432 f/6 apo telescope, iOptron CEM25P mount, Altair Astro Tri-Band 2-inch filter **Exposure:** 72x180" light frames, 20 dark frames, 30 flat frames and 30 flat darks **Software:** Siril, Photoshop



△ Perseid and Andromeda

Viljam Takis, Soomaa National Park, Estonia, 12 August 2019

Viljam says: "I took a stack of photos of Andromeda and caught a Perseid in one. This is the stack of 30-second frames blended with the one that the Perseid appeared."

Equipment: Sony Alpha a7S II camera, Meade AP70/350 f/5 quadruplet refractor, iOptron SkyGuider Pro tracker
Exposure: ISO 10,000, 253x30",
Software: MaxIm DL, Photoshop

◁ Occultation of Geminorum

David Bryant, Norfolk, 27 August 2019

David says: "I knew about the occultation of Geminorum and I was in my back garden and ready for it at 4:15am. It took a few attempts to get both correctly exposed."

Equipment: Pentax K-3 camera, SMC 300 prime lens, 1.4x converter, Husky tripod **Exposure:** ISO 800, 1/100", **Software:** IrfranView

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We've teamed up with Altair Astro UK to offer the winner of next month's *Gallery* an Altair Astro Planet-Killer 685nm Premium IR Pass Filter with AR coating, designed to deliver sharper lunar and planetary images with mono CCD or CMOS cameras. For more info visit: **www.altairastro.com • 01263 731505**

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86

The Altair 150 EDF refractor packs in a generous aperture and superb optics for observing, but how does it fare for astro imaging?

PLUS: Books on space junk, the life of outspoken astronomer Fritz Zwicky, and a roundup of the latest of gear

HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★★ Very good
★★★★★ Good ★★★★★ Average ★★★★★ Poor/avoid

Altair 150EDF apochromatic doublet refractor

An all-rounder, combining pinpoint focus and natural colours with imaging capability

WORDS: TIM JARDINE

VITAL STATS

- **Price** £2,599
- **Optics** S-FPL53 apochromatic doublet
- **Aperture** 150mm (6-inch)
- **Focal length** 1,200mm, f/8
- **Focuser** Dual-speed 1:10 rack and pinion
- **Extras** None
- **Length with dew shield retracted** 1m
- **Weight** 10.7kg
- **Supplier** Altair Astro
- **Tel** 01263 731505
- **www.** altairastro.com

For many telescope enthusiasts, a long focal length, 6-inch (150mm) refractor like the Altair 150EDF represents the ultimate piece of equipment, perhaps offering the largest sensible aperture that is practical for dedicated amateurs.

The proportions of the 150EDF are impressive, an f/8 lens giving a focal length of 1,200mm, making it a long scope, especially with the dew shield extended. We mounted it onto our permanent pier (post) in a compact observatory and it quickly dominated the observing area. Long refractors make for some interesting observing positions, so it's prudent to think about how and where you might mount and use one.

After allowing a couple of hours for the scope to adjust to the ambient temperature we performed a star test to make sure the optics had survived the shipping process, although in regular use we found that generally 30 minutes cooling time was enough. The telescope tested well, and returned a clean, round pinpoint star image, with a good airy disc at focus. Ramping the magnification up to an extreme 535x demonstrated the capability of the optics to deliver high-quality star views, and it really whet our appetite for some double-star observing.

Going after the gas giants

The 150EDF will appeal especially to observers who enjoy our Solar System's objects, and although circumstances conspired to deny us any lunar or solar viewing sessions, the views it produced of both Jupiter and Saturn were quite outstanding – despite these two being very poorly positioned for UK observers this season. Our 10mm eyepiece produced 120x magnification, which gave a sensible compromise given the seeing conditions at Jupiter's low altitude, and revealed clear natural colours, patterns and deviations in the belts and a distinct Great Red Spot. Saturn, slightly higher, was even more impressive, accepting 240x magnification and displaying coloured bands on the disc, with a sharp, clean Cassini Division and some variations in the rings too. We even managed a peek at Neptune, which displayed a clear disc shape. ▸

In glowing colours

The quality of the view at an eyepiece, or camera, is affected by the colour correction of the optics. Perfect optics bring all colours together to a single point of focus, providing the sharpest views. Less capable lenses produce bright haloes of colour around bright objects. For years, natural fluorite lenses were favoured for their colour-handling properties, but had undesirable qualities too, being brittle and expensive. The Altair 150EDF's apochromatic doublet lens uses S-FPL53 manufactured glass, which has a refractive index similar to fluorite, without the problems. Our views of Saturn and Jupiter were natural, with no evidence of colour aberrations at all. Tests with a camera and filters confirmed that Red, Green, and Blue wavelengths of light come to a close point of focus in the 150EDF, even comparable with premium triplet lens refractors. It's this impressive correction that allows the use of higher power eyepieces while maintaining sharp star images, so you can push magnification further as conditions allow.

Focuser

Suitable for observing or photography, the dual-speed rack and pinion focuser is smooth, precise and fully rotatable. The drawtube has marked millimetre graduations and extends 95mm. A star diagonal is necessary to achieve eyepiece focus, and an extension tube is needed for a camera if used without a diagonal.

Size and scale

With the dew shield and focuser extended, the 150EDF is 140cm in length and weighs around 10kg, but we found it to be quite manageable and we mounted it single-handedly. Accessories like cameras or diagonals add length and weight and help to counterbalance the front-heavy scope.

Tube rings

The 150EDF is supplied with well-machined rings, with a fitted Vixen-style dovetail bar on the bottom and a rounder-style bar on top. This acts as a carrying handle or an accessory-mounting rail with multiple fitting points.

Baffles

Peering down through the lens reveals a series of internal tube baffles, which decrease in size as they get nearer to the focuser. These act as light-blocking barriers and reduce the impact that unwanted light sources have on the scope views.

Dew shield

The dew shield protects the objective lens from the unwanted effects of dew and stray light. It can be fixed in place with an Allen key (not supplied) and lengthens the scope by 22cm, making a difference to its size and balance.

KIT TO ADD

1. Altair PlanoStar flattener
2. Altair 24mm Ultraflat eyepiece stainless steel barrel
3. Altair 2-inch Positive Lock prism diagonal

▸ Moving out of the Solar System and onto some favourite double stars, we turned first to Epsilon (ε) Lyrae, the Double Double. As expected, the split here was clean, and using a 2x Barlow lens and 4.5mm eyepiece at 535x provided a superb view: all four stars round and distinct with perfect airy discs just touching for each pair. Positioned high overhead, the viewing position was awkward, but well worth it for the view. Next was Iota (ι) Cassiopeiae, an intriguing multiple star system, with three observable close stars offering varying colours. These were easily split and the colour distinction was obvious.

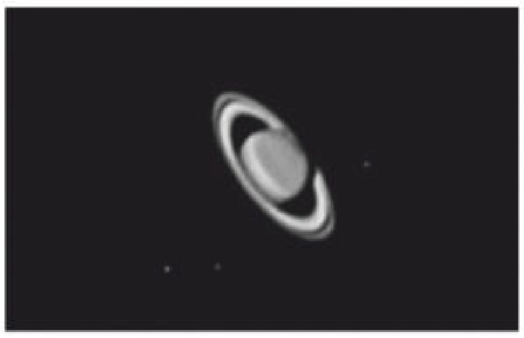
Sitting pretty

With the scope's technical credentials demonstrated by the high-magnification viewing, it was time to enjoy the prettier sights. Albireo was delightful, the star cluster M52, sharp and spangly, and in a 21mm, 100° eyepiece, the Andromeda Galaxy was almost touchable, flanked by its companions M32 and M110. The same eyepiece drew on the Altair's 150mm window to provide a stunning visual offering of the Double Cluster in Perseus, confirming the advantages of a large aperture refractor for visual astronomy.

Such enjoyable visuals left us wondering how the scope would perform with a camera attached. With no field-flattener available to us, we used our small-chip Atik 460 cameras for both mono and colour images. This gave a flat result with no effects from coma even in the corners, and the star images were tight and round throughout, even with the OSC (One Shot Colour) camera that we used on smaller targets like M27, M57, and Albireo, to capitalise on the 150EDF's long focal length. Turning to the Bubble Nebula, NGC 7635, a favourite narrowband target, a mono camera with narrowband filters revealed the good contrast and faint light transmission offered by the telescope lens.

With excellent all-round visual performance and imaging capability, the Altair 150EDF is sure to be at the top of many hobbyist wish-lists.

▲ NGC 7635, taken with an Atik 460 mono camera, with 12x10' exposures in OIII and 9x10' exposures in Ha, and a total integration of 3 hours 30 minutes



▸ Saturn, captured with a DMK 618 mono camera and 2x Powermate lens, using the best 30 per cent of 10,000 frames

▲ Albireo, taken with an Atik 460 OSC, using 20x30" exposures and a total integration of 10 minutes

▲ M27, again with an Atik 460 OSC, using 15x10' exposures and a total integration of 2 hours and 30 minutes

VERDICT

Build & Design	★★★★☆
Ease of use	★★★★☆
Features	★★★★☆
Imaging quality	★★★★☆
Optics	★★★★★
OVERALL	★★★★☆

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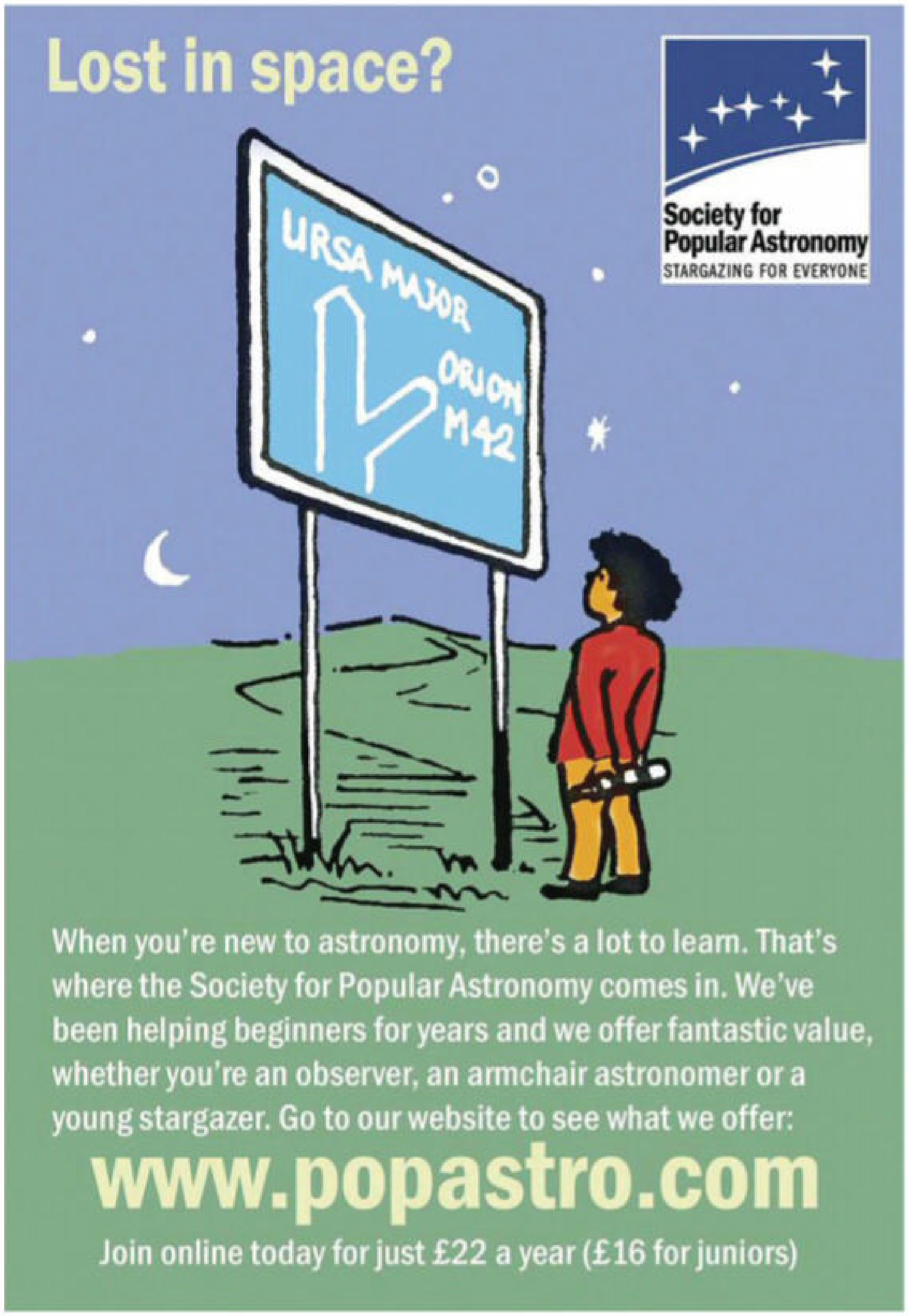
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Our experts review the latest kit

FIRST LIGHT

Celestron Astro Fi 6
Schmidt-Cassegrain telescope

An enjoyable and lightweight setup that can be controlled via your smartphone or tablet

WORDS: PAUL MONEY

VITAL STATS

- **Price** £649
- **Optics** 150mm (6-inch) SCT compound telescope with StarBright XLT coatings
- **Focal length** 1,500mm, f/10
- **Mount** Wi-Fi computerised altazimuth single fork arm
- **Ports** Power connector, two aux ports, integrated Wi-Fi adaptor, on/off switch
- **Tracking rates** Sidereal, lunar and solar
- **Tripod** Adjustable with accessory tray, including smartphone holder
- **Extras** StarPointer red dot finder, 25mm and 10mm 1.25 inch eyepieces and star diagonal, battery pouch
- **Weight** 6.71kg
- **Supplier** David Hinds Limited
- **Tel** 01525 852696
- **www.** celestron.co.uk

With the advent of modern smartphones it wasn't long before Celestron brought out its Astro Fi range where, using Celestron's free SkyPortal app, you can fully control an altazimuth Go-To computerised telescope without the need for the traditional handset. The range went up to the Astro Fi 5 Schmidt-Cassegrain telescope (SCT), which we reviewed in June 2018, but now Celestron has added a 6-inch (150mm) SCT to the range and we've been eager to test this new model.

The Astro Fi 6 is an SCT with a focal length of 1,500mm that gives a focal ratio of f/10. The optics have Celestron's proprietary StarBright XLT coatings, giving better contrast for planetary and lunar observations, along with higher light transmission for deep-sky targets. The long focal length fits neatly into a compact, lightweight tube. This is easy to lift onto, and attach to, the mount. Complementing the optics is a 'visual back', allowing the supplied 1.25-inch star diagonal to be used along with two Kellner eyepieces, 25mm and 10mm, giving a good range of magnification of 60x and 150x. A StarPointer finderscope (red dot finder) and a basic, but useful, smartphone holder that can accommodate most smartphone brands is also provided.

Child friendly

The mount is a single arm, computerised Go-To altazimuth mount with a Vixen- (or CG-5-) style adaptor. It's easily fitted to the aluminium tripod via the captive knob under the top of the tripod. A battery pouch for 8xAA batteries is provided (although batteries are not included) and the mount can also be powered by a power tank. The tripod has extendable legs, providing a good range of adjustment and making it ideal for children when it's positioned at a low height.

As with other telescopes in the Astro Fi series, the Fi 6 is not supplied with a handset. Instead, the mount incorporates the Astro Fi Wi-Fi network to allow control via a smartphone or tablet. By downloading ▸

Lightweight and versatile

We were impressed with how easy the Astro Fi 6 SCT was to assemble, set up and use for a variety of purposes. With a tube weight of just 2.17kg, mount weight of 2.3kg and tripod at 2.3kg, each is just over a couple of bags of granulated sugar in weight. The optical tube is just 406mm long with a diameter of 155mm, making it compact for an f/10 system. This makes it an ideal setup for youngsters while giving a decent size of aperture to allow good views of so many objects.

An altazimuth Go-To system is traditionally best for visual observations, especially of the planets and the Moon, but the brighter deep-sky targets were also seen well in our tests. Throw in the smartphone control, and basic but useful smartphone holder, and the system takes on a new role for astrophotography. We captured short exposures with our smartphone of the Moon and brighter deep-sky objects too, showing just how versatile it really is.

SCALE

Single arm Go-To alt-azimuth mount

The single arm mount is well made, solid and fits neatly into the tripod base, being held in place by a large plastic knob. The mount has a Vixen-style saddle for attaching the telescope, with a good chunky retaining bolt giving a solid grip to the scope.

Tripod

The simple but effective tripod has aluminium telescopic legs that can be extended to give a range between 86cm and 137cm. The mount attaches easily with a single underside bolt from the tripod which holds it firmly in place. The spreader tray can hold two 1.25-inch eyepieces and there is an integrated rubberised smartphone holder.

Optics

The Astro Fi 6 SCT comprises a primary mirror and a corrector plate (with the secondary mirror attached to the corrector) and StarBright XLT coatings for improved light transmission. It has a 'long' focal length of 1,500mm, giving a focal ratio of f/10, making it ideal for both planetary and deep-sky viewing.

Accessories

The StarPointer red dot finder is useful for the initial alignment. Two eyepieces are provided, 25mm and 10mm, giving magnifications of 60x and 150x, along with a 90° star diagonal. A useful extra is the basic but functional smartphone holder, adding a new dimension to the setup.

FIRST LIGHT

KIT TO ADD

1. Celestron PowerTank Lithium

2. Celestron C6 dew shield

3. Celestron Moon filter set, 1.25-inch

▸ the Celestron SkyPortal app (android and iOS) and connecting to the mount's Wi-Fi signal, you can connect and align with your smart device. We used our iPhone 7+ and iPad Pro to connect with no difficulty, using SkyPortal which is based on the SkySafari app. Once aligned there is plenty to explore each night, with 120,000 stars and over 200 deep-sky objects to choose from, along with planets, moons, asteroids and comets. We also found we could connect using SkySafari Pro 6, so if your system supports these apps then you should be able to connect and operate the scope.

Bright ideas

Optically, we enjoyed crisp views of Jupiter and Saturn despite their low altitudes, with the Cassini Division just discernible and the belts of Jupiter and its Galilean moons seen easily. Our Moon was detailed, with the 10mm eyepiece giving good views as we explored the waning gibbous Moon replete with craters, including a view of Theophilus, Cyrillus and Catharina. Using the app we took a tour of the brighter Messier objects, including the stunning Great Globular Cluster, M13, the Ring Nebula, M57, the Dumbbell Nebula, M27, the Wild Duck Cluster, M11 and the Omega Nebula, M17. We could catch a view of M81 and M82 – the galaxy pair in Ursa Major – just fitting in the view of the 25mm eyepiece. We also enjoyed a good colourful view of Albireo, and with the 10mm eyepiece we could make out the three components of Iota (ι) Cassiopeiae.

We also explored what the smartphone holder could capture with the 25mm eyepiece. We imaged deep-sky targets, mainly star clusters that were bright enough to capture with our iPhone using the NightCap Camera app. We found it was best to connect the mount using our tablet, as this left the smartphone free for imaging.

If you don't wish to use a smart device to control the system, you can buy the optional handset, but we found it was a very enjoyable experience controlling the Astro Fi 6 with our smart devices. In fact, it proved itself as the next step in smart telescope control.

VERDICT

Assembly	★★★★★
Build & Design	★★★★☆
Ease of use	★★★★☆
Features	★★★★☆
Optics	★★★★☆
OVERALL	★★★★☆

▲ The Moon, captured with an iPhone 7+ and NightCap Camera app paired with the Astro Fi 6, using a 25mm eyepiece

▸ M13, taken with a 25mm eyepiece, using the NightCap Camera app with a 5.4 second exposure at ISO 3520

Ports and Wi-Fi

The mount incorporates two aux ports; one can be used for an optional hand controller and the other is spare. Above them lies the integrated Wi-Fi for connecting to the SkyPortal app. At the front is an on/off switch and a 12V DC power connector is provided.

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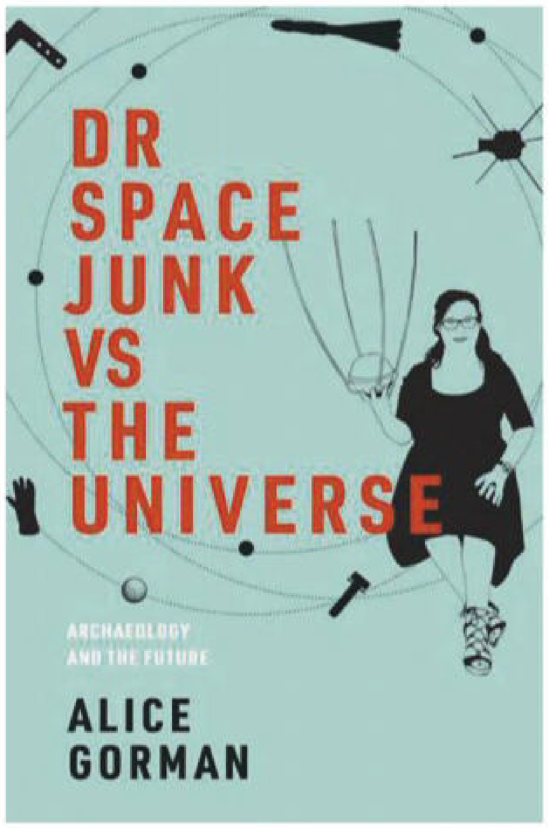
BOOKS



Dr Space Junk vs The Universe

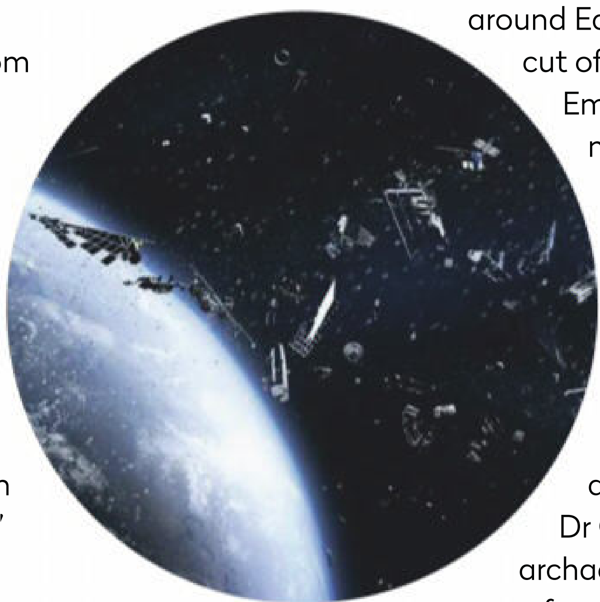
Dr Alice Gorman
The MIT Press
£22.50 ● HB

"Space junk ranges from whole spacecraft that weigh thousands of kilograms, to microscopic particles from eroded spacecraft surfaces. The entire bulk of this detritus is equivalent in weight to 1,000 African male adult elephants." The junk in question, defined by Dr Alice Gorman, is any material from the space sector (pieces of antennae, spent rocket stages, satellites, and crew or cargo modules) that has been left behind on Earth or is floating free in space. To Dr Gorman, whose background is in archaeology, these bits of space junk are artefacts of human history and should be given just as much credence as the relics found in caves, pyramids or ancient settlements.

Like any archaeological artefact, space junk can reveal a lot about us and our past, explains Dr Gorman, whether it's discarded cable ties around a defunct terrestrial antenna in Australia, shards of satellite that have fallen to Earth, or unmanned space stations orbiting our planet. She highlights the significance of this seemingly worthless junk, as well as delving into appropriate methods for preserving it and the issues surrounding moving fallen space debris from its landing site.

The stories from the author's archaeological career and the chronicles of the history of space junk are interesting, but at times told a little too extensively. The later chapters explore the broader anthropological significance of space junk today and in the future. "There are over 23,000 bits greater than 10cm and millions of bits smaller than that," she explains.

A worst-case scenario for space junk has been predicted. Called the Kessler syndrome, it's "when a cascade of random collisions could create so much debris around Earth that we will be cut off from space".



▲ What lessons can we learn from space junk?

SLAVEMOTION/ISTOCK/GETTY IMAGES

Emerging space players must consider the environmental management of their satellite deployment to avoid this scenario, she warns.

The book has appeal because of Dr Gorman's unique archaeological perspective of space junk. She ends by telling us that space artefacts of our past should remind us of what we want to hold on to in the years to come, because how we deal with space junk now is a big part of that. Wise words indeed.

★★★☆☆

***Niamh Shaw** is a science communicator, engineer and performer*

Interview with the author
Dr Alice Gorman

How did you go from archaeologist to space junk expert?

I was a regular archaeologist, specialising in the study of stone tools, but I always had a secret ambition to be an astrophysicist. One day, while looking at the night sky, it struck me that Earth was circled by space junk. Studying what people discard is pretty much what archaeologists do; I'm just working on a more recent type of artefact.

Are we filling the Solar System with our trash?

We shouldn't unnecessarily pollute the Solar System, but I don't think every human artefact is trash, either. Archaeological sites in space are the material evidence of one planet and its history in the Galaxy. We need a balance between acknowledging our heritage and being responsible citizens of space. Otherwise we might create a prison planet, where the bars are made of space junk.

What's your favourite space junk?

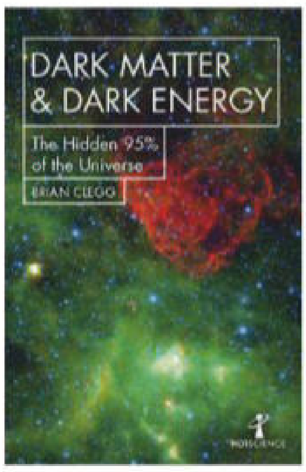
Vanguard 1, the oldest human object in Earth orbit, launched in 1958. Another is Australis-OSCAR 5, an Australian student-built satellite launched in 1970. I'm also interested in the millions of tiny particles produced by spacecraft in decaying orbits and what these mean for the near-Earth space environment.

What would an extraterrestrial visitor make of it all?

They'd look at our spacecraft as evidence of the society that made them. At the moment, space culture is mostly robotic. Visitors might conclude we have fragile bodies that can't survive in space.

***Dr Alice Gorman** is a pioneer in the emerging field of space archaeology*

Dark Matter & Dark Energy: The Hidden 95% of the Universe



Brian Clegg
Icon Books
£8.99 ● PB

Astronomy has enabled humankind to make many discoveries about the Universe, but despite the centuries of study and the insights we've gained, we've barely scratched the surface. In the past few decades, it's become clear that we have focused on just 5 per cent of the Universe – the rest remains almost entirely unknown.

Astronomers divide this mysterious majority into two types of 'stuff': dark matter (a substance with five times more mass than all the visible matter in our Universe and detectable only through its gravity), and dark energy (a force that is driving space apart at an accelerating rate). Brian Clegg's book is a clear and compact look at the current state of knowledge about these twin cosmic mysteries.

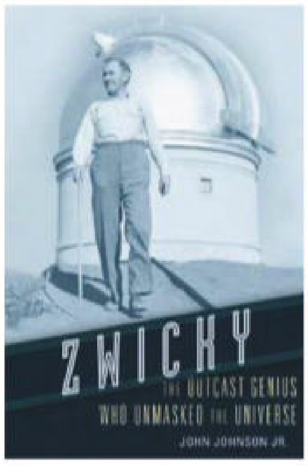
Clegg's engaging prose tackles the fundamentals at a brisk pace. After an introductory account of the discovery of both phenomena, the book's first half focuses on dark matter, reviewing the building blocks of our visible Universe and the evidence for dark matter, before an informative overview of the various candidates for what it might be.

The second half covers dark energy, with basic cosmological groundwork followed by a discussion of dark energy and what it could mean for the future of the cosmos. The book concludes with a look at the latest research, unanswered questions and future prospects. All in all, it's hard to fault as a brief, easily digestible introduction to some of the biggest questions in the Universe. ★★★★★

***Giles Sparrow** is a science writer and fellow of the Royal Astronomical Society*

Zwicky: The outcast genius who unmasked the Universe

GRIPPING READ



John Johnson Jr
Harvard University Press
£28.95 ● HB

Fritz Zwicky is a name most astronomers learn early in their careers, due to both his scientific achievements and his combative personality. This biography explores the life of this world-renowned physicist.

Instead of Zwicky's early life, the book starts with an overview of the state of physics research in the US around the turn of the 20th century – a time when the field was surprisingly young. The chapters are roughly chronological, though seem more thematically linked. The only disadvantage is it's sometimes easy to lose track of what year the story is in, though that's largely because the 1940s were so hectic.

The book spans an eventful period in world history that formed the backdrop to Zwicky's astronomy research, along with his contributions to the US war effort and rocketry. It includes details of many of Zwicky's personal encounters, putting his various feuds and confrontations in context (including his infamous name-calling, which ranged from "horses' asses" to "spherical bastards"). It ends with some touching tributes to a complex personality who was both loved and loathed in his time.

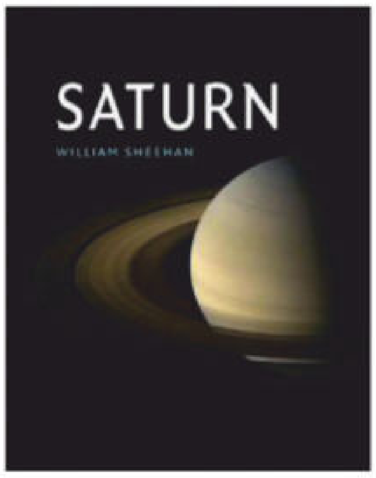
It discusses the science briefly, but accurately, though the focus is on the personal interactions. Interspersed are a few snippets about the search for "Zwicky's Ghost" – dark matter, one of Zwicky's more famous predictions.

If you're after a book about the science Zwicky was involved with, this one isn't for you – it's a biography. It is, however, interesting to read and provides an insight into a rich, complicated character and his engagement with the world he was part of. ★★★★★

***Dr Chris North** is the Odgen science lecturer at Cardiff University*

Saturn

William Sheehan
Reaktion Books
£25 ● HB



Saturn is a detailed exploration of the most well-known of the ringed planets in our Solar System. It's an amazing account of how much we can learn from so little; how, over time, new things slowly reveal themselves; and how many questions we have yet to answer about this infamous giant world.

This book manages to show how – with the help of Galileo and his early telescopes – Saturn went from being a pale orange dot wandering across the constellations, to a body vital to the development of ground-based astronomical observations. Sheehan relates the story in detail, but keeps it exciting as he spins the tale of the planet's role in human history, from ancient Mesopotamia to modern-day space missions.

As well as drawings from early observations of Saturn, the book features some spectacular images taken by the Cassini orbiter and other missions, which combine with Sheehan's writing to show how our understanding of the planet has gradually deepened over the centuries. The book concludes with a detailed guide to observing Saturn in the hope that further monitoring, by both amateur and professional astronomers, will help to reveal the planet's many remaining secrets.

Saturn is a must read for any enthusiastic amateur astronomer armed with a small telescope and the curiosity to learn more about the planet, its rings and moons. But this book is ultimately a trainspotter's guide and while the casual reader may find it interesting, it is easy to get lost in the detail.
★★★★½

***Hannah Wakeford** is an astronomer who studies the atmospheres of exoplanets at the Space Telescope Science Institute*

Elizabeth Pearson rounds up the latest astronomical accessories

GEAR

1 Spiral galaxy meteorite pendant

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https://thespacecollective.com

This swirling galaxy necklace holds a fragment of our Solar System at its heart in the form of a meteorite. It's made from solid sterling silver on a 20-inch chain and comes with a certificate of authenticity.

2 Celestron dielectric star diagonal

Price £139 • **Supplier** Harrison Telescopes
Tel 01322 403407 • **www.harrisontelescopes.co.uk**

This diagonal bends the light from your telescope by 90°, allowing you to look through the eyepiece at a more comfortable angle. It uses a twist lock so you can easily centre your optical equipment. The diagonal is available in both 1.25- and 2-inch sizes.

3 Sky-Watcher Synscan StarWand

Price £129 • **Supplier** Tring Astro
Tel 01442 822997 • **www.tringastro.co.uk**

Point and go – literally – with this device. Once you've set up the system, you can use the StarWand's laser to indicate any point on the night sky, and any connected telescopes will automatically slew to that location.

4 Altair OSC TriBand filter

Price £215 • **Supplier** Altair Astro
Tel 01263 731505 • **www.altairastro.com**

This filter enables you to capture hydrogen-alpha, hydrogen-beta and OIII lines simultaneously, allowing you to capture more information in a short amount of time, while also bringing out the detail of nebulae and suppressing light pollution.

5 Space Shuttle T-shirt

Price £19 • **Supplier** Rapanui
https://rapanuiclothing.com

A Space Shuttle ascends into the sky on a colourful cloud of exhaust in this T-shirt's design. Printed on an ethically and sustainably produced cotton shirt, it's available in both men's and women's fit.

6 Orion Dynamo Pro 155Wh lithium power supply

Price £172.99 • **Supplier** Orion
Tel 0800 041 8146 • **https://uk.telescope.com**

Power through the night with Orion's Dynamo Pro. Compact and portable, this power tank will keep your equipment running wherever you set up for the night. It includes multiple USB and DC ports, as well as a built-in, standard 3-pin plug socket.

Shaoni Bhattacharya interviews Dominik Koll

Q&A WITH A SUPERNOVA SLEUTH

Supernovae are usually observed hundreds, if not thousands, of lightyears away but one research team is looking for signs of stellar explosions closer to home

▲ **Snow patrol: Antarctic-based researchers from the Alfred Wegener Institute sourced snow samples with iron-60 for Dominik Koll's team**

What did your study look at?
We analysed 500kg of Antarctic snow, looking for an isotope called iron-60, a radioactive form of iron which contains four extra neutrons. This is mostly produced in supernovae, so finding iron-60 means there's direct evidence we have interstellar material falling onto Earth.

Why did you use Antarctic snow?
Antarctic snow is one of the purest materials you can find on Earth. There are almost no contaminants from terrestrial sources in the snow. The snow fall rate is also very low, with only a few events a year that precipitate snow. That means the dust is concentrated, so we don't need large amounts of snow to find the elements we are looking for.

How did you get the snow?
We have colleagues in Antarctica from the Alfred Wegener Institute who have a research station there. We asked them to shovel 500kg of snow and pack it into 25 containers. This was transported by plane towards the coast of Antarctica, then by ship to South Africa, and then to Germany. It came to Germany frozen, which was crucial because we wanted to make sure all the dust – including the interstellar material – was contained within the snow; as it melts you lose it to the container and the environment. Then we melted and filtered the snow under controlled conditions, separating it into the filter sample and the water sample, which we then tested.

What were you looking for?
The initial hypothesis was that there should be iron-60 around our Solar System from interstellar sources. Earth is currently in or on the border of the Local Interstellar Cloud (LIC) – a 30 lightyear-wide region possibly formed by supernovae – which the Solar System has been traversing for around 40,000 years. The LIC would have been spiked with iron-60 from these supernovae in the past.

How did you know the iron-60 was from an interstellar source?
Iron-60 is produced by supernovae and cosmic ray interactions. We can distinguish between them by looking at another element, manganese-53, which is dominantly produced by cosmic ray interactions. We know the amount of manganese-53 compared to iron-60 from these interactions by analysing meteorites and cosmic dust. There is a constant ratio between the two isotopes. If you find more iron-60 than implied by this ratio, this suggests you have some from interstellar space.

What did you find?
We found interstellar iron-60, but at the moment Earth is almost on the point of leaving the LIC. To investigate if the hypothesis is true we should look at past eras when the Solar System was entering the LIC. You should see an increase of iron-60. If in the past there is no iron-60 this would be the final evidence for this LIC hypothesis.

Dominik Koll is a PhD student at the Australian National University, studying how we can use iron-60 to understand the cosmos. He conducted the study at the Technical University of Munich

What is the next step?
The next step is to take older material than we've already looked at, outside the window of time the Solar System has been inside this LIC. We have to look at snow that's about 100,000 years old. If we see no iron-60 in this very old material, this would mean that the iron-60 came into the Solar System and fell onto Earth around the time we entered the LIC. If there is still iron-60 this far back, however, it means the LIC is not the main source of iron-60, but that iron-60 has in fact been around in the Solar System for a long time. This would be interesting as we currently have no simple explanation for that occurrence.

THE SOUTHERN HEMISPHERE

With Glenn Dawes

Planet spotting is still the name of the game, with a close meeting of Venus and Jupiter

When to use this chart

1 Nov at 24:00 AEDT (13.00 UT)
15 Nov at 23:00 AEDT (12.00 UT)
30 Nov at 22:00 AEDT (11.00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

NOVEMBER HIGHLIGHTS

Jupiter is impressive in the western early evening sky, directly below the Teapot of Sagittarius. This gas giant is outshone by brilliant Venus which is lower and closer to the horizon during twilight. Starting the month 23° apart, the planets slowly move together, with Venus overtaking on the 24th, separated by only 1.4°. The thin crescent Moon joins the duo on 28th just 2° below Jupiter, making an impressive sight in the twilight sky.

STARS AND CONSTELLATIONS

High in the southern evening sky is Achernar, the isolated bright 'alpha' star of Eridanus, the River. Its name comes from the Arabic for 'the river's end', but it didn't always have this name or indeed belong to this constellation. Historically, the star called 'Achernar' at the end of Eridanus was today's Acamar (Theta (θ) Eridani). When 16th-century travellers discovered current Achernar below the southern horizon, they shuffled the names and elongated the river.

THE PLANETS

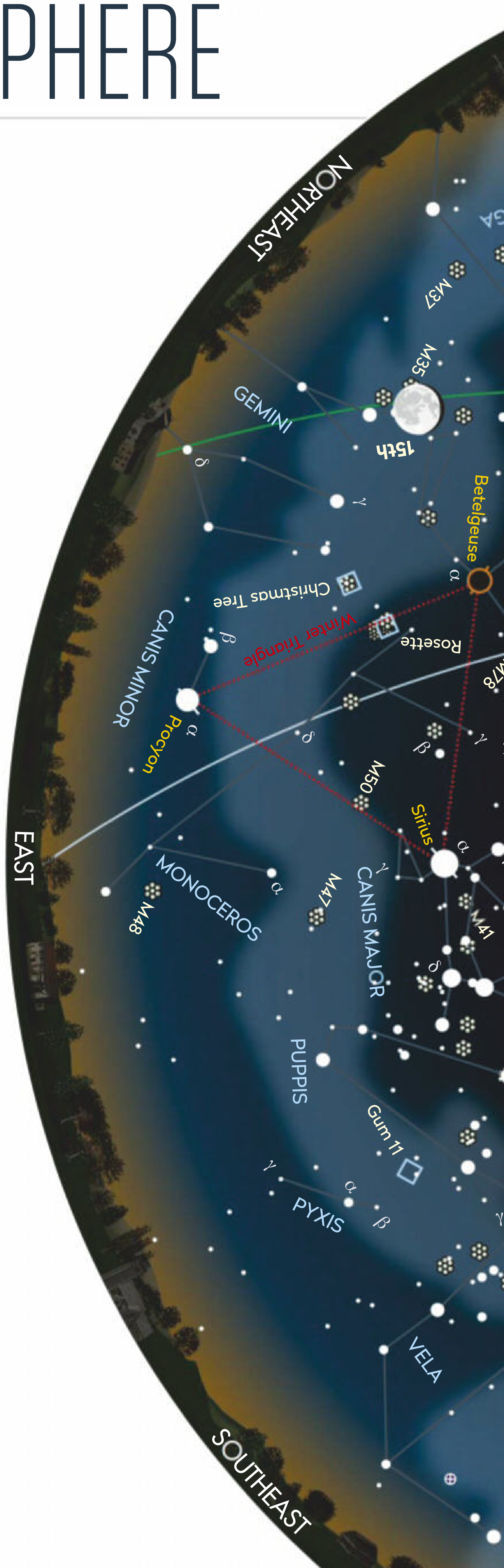
The feast of planets continues, with four naked-eye planets visible as November opens. Mercury and Venus are twilight objects, although Mercury drops into the Sun's glare after a week. Above Venus is Jupiter, departing around 21:30 midmonth, with Saturn following two hours later. Neptune is well placed, transiting in the early evening, with Uranus following three hours later. The remaining planet, Mars, has now returned to the morning sky but remains low at dawn this month.

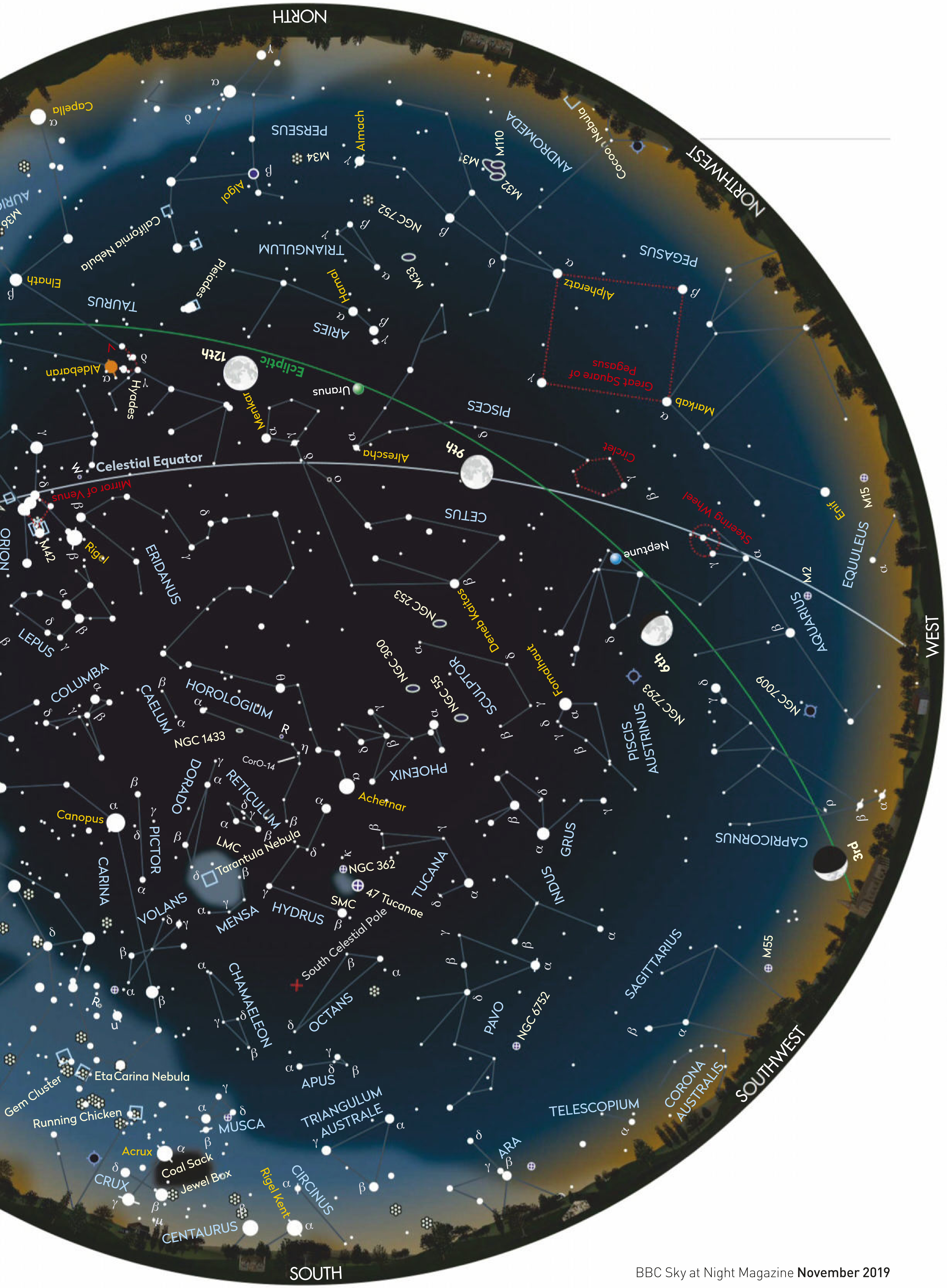
DEEP-SKY OBJECTS

Let's take a trip to the deep south, to the lesser known constellation of Horologium. The double star CorO 14 (RA 2h 38.7m, dec. –52° 57') is easy to find, being only 0.5° south-southeast of naked-eye (mag. +5.3) star Eta (η) Horologii. CorO 14 has mag. +7.9 and mag. +8.7 components that are white and yellow respectively, separated by a comfortable 9 arcseconds. As a bonus, CorO 14 forms an easy binocular double with a brighter (mag. +6.8) star 4 arcminutes eastward.

Isolated barred spiral galaxy NGC 1433 (RA 3h 42.0m, dec. -47° 13') is worth the hunt. Images of this 10th-magnitude galaxy show a bright core and bar with two bright spiral arms extending from its ends. Visually NGC 1433 shows a bright halo (approx. 3'x2') with a hint of a central core with a star-like nucleus.

CHART: PETE LAWRENCE





NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
Capella
PERSEUS
Almach
M34
Algol
M110
M31
M32
ANDROMEDA
Cocoon Nebula
California Nebula
TRIANGULUM
NGC 752
M33
PEGASUS
Elnath
TAURUS
Pleiades
Hamal
ARIES
Alpheratz
Great Square of Pegasus
Aldebaran
Hyades
12th
Ecliptic
Uranus
Menkar
PISCES
Markab
Alrescha
Circlet
9th
Celestial Equator
Mirror of Venus
CETUS
Steering Wheel
Enif
M15
ORION
M42
Rigel
ERIDANUS
Neptune
EQUULEUS
M2
AQUARIUS
NGC 253
Deneb Kaitos
LEPUS
6th
NGC 300
SCULPTOR
Fomalhaut
COLUMBA
CAELUM
HOROLOGIUM
NGC 55
NGC 7293
NGC 7009
PISCIS AUSTRINUS
NGC 1433
CorO-14
PHOENIX
DORADO
RETICULUM
Canopus
Achernar
CAPRICORNUS
3rd
PICTOR
LMC
Tarantula Nebula
GRUS
CARINA
NGC 362
47 Tucanae
TUCANA
INDUS
VOLANS
MENSA
HYDRUS
SMC
South Celestial Pole
SAGITTARIUS
M55
CHAMAELEON
OCTANS
PAVO
NGC 6752
Eta Carina Nebula
Gem Cluster
APUS
TRIANGULUM AUSTRALE
TELESCOPIUM
CORONA AUSTRALIS
Running Chicken
MUSCA
Acrux
Coal Sack
Jewel Box
CRUX
Rigel Kent
CIRCINUS
ARA
CENTAURUS